The Dock & Harbour Authority

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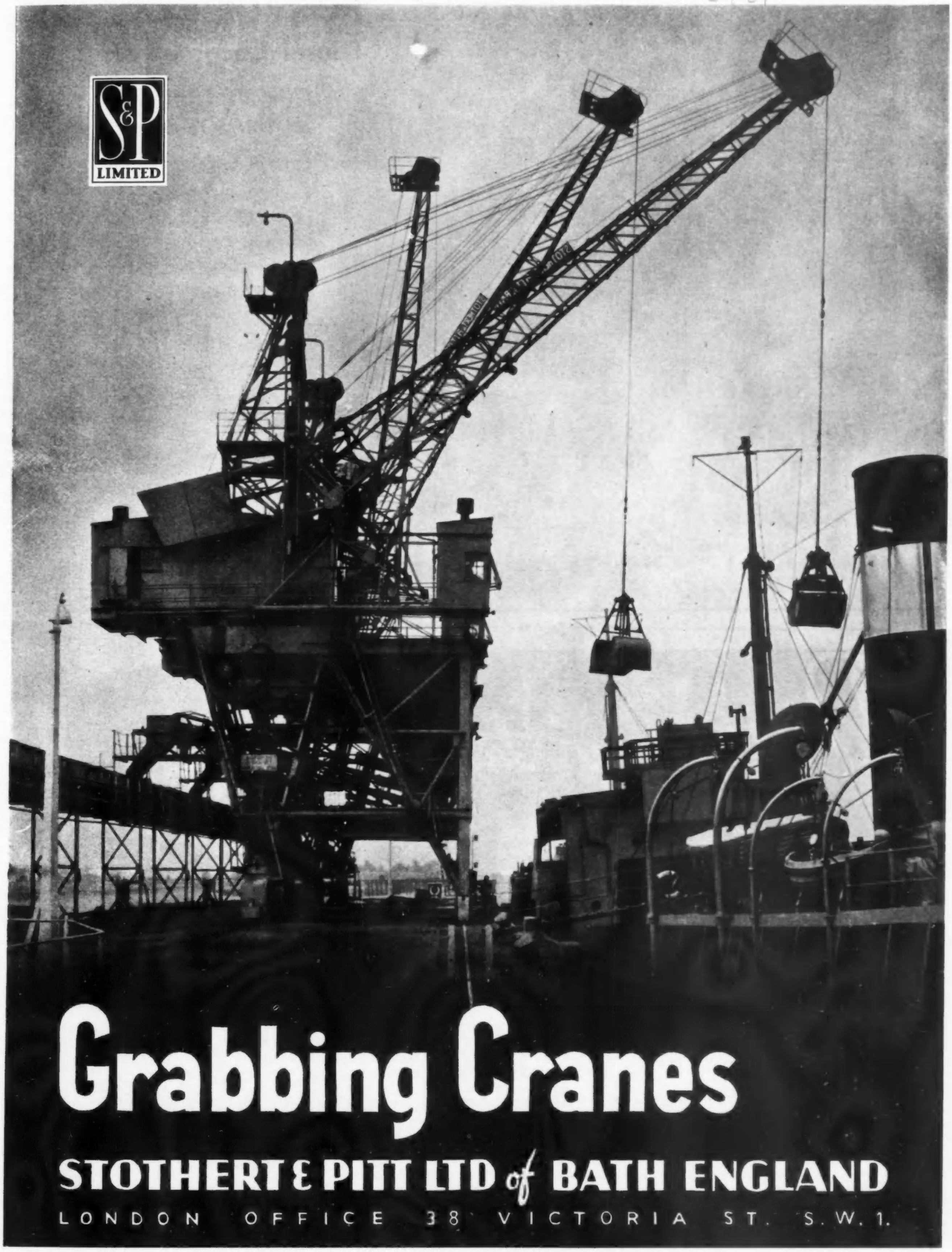
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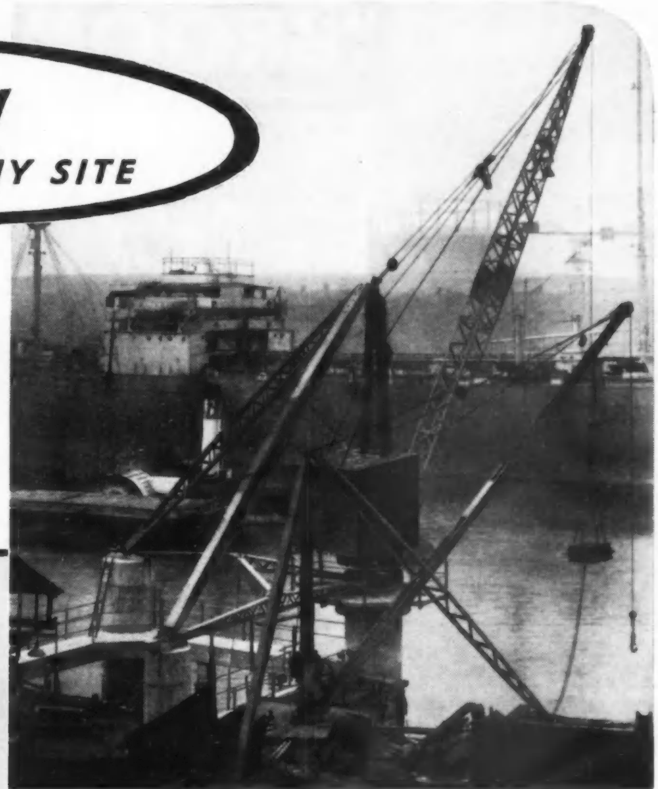

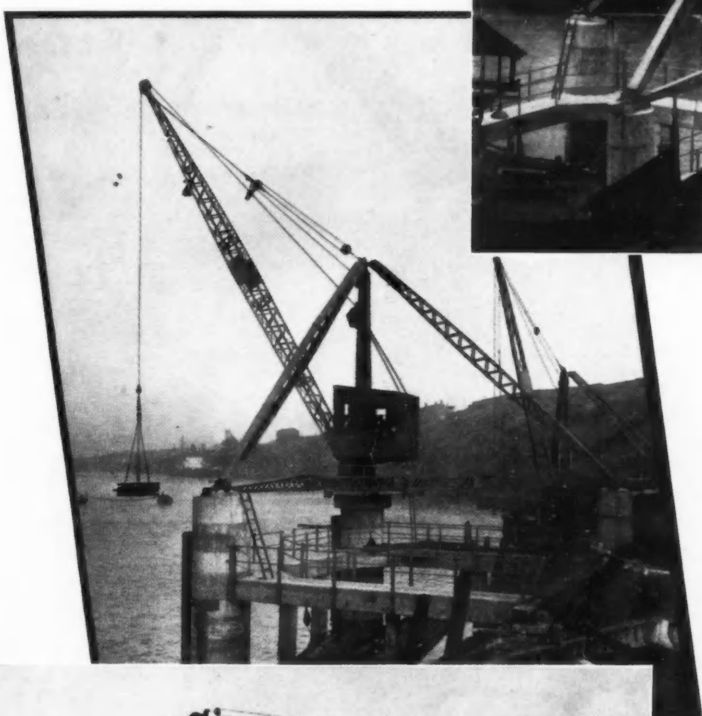

To Correspondents

All Letters and Contributions intended for Publication should be addressed to the Editor:—
K. R. Doggett, Assoc.I.C.E.,
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The Dock & Harbour Authority

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The Dock and Harbour Authority

No. 379 Vol. XXXIII MAY, 1952 Monthly 2s. 0d

Editorial Comments

The Ports of Wilmington and Morehead City.

The January and February, 1943, issues of this Journal contained an article which described in considerable detail the pre-war port and harbour of the Port of Wilmington, North Carolina, U.S.A. Readers will be interested, therefore, in the contribution which appears on another page in the present number, recording the extensions and improvements which have been made at this North American port during the intervening years.

Since the recent war, the Ports of Wilmington, Morehead City and Southport, have been incorporated in an autonomous body known as the North Carolina State Ports Authority, and acting upon the wide powers conferred upon it, the new Authority immediately took steps to improve port facilities at the Port of Wilmington, which is situated on the South-Eastern sea-board of the State, and at Morehead City, 90 miles further north on the Beaufort Inlet which lies behind Cape Lookout.

The approaches to these two ports vary considerably. At Morehead City a short dredged channel with a depth of 30-ft. at mean low water connects the port area with the sea. At Wilmington, on the other hand, access to the port is through a dredged channel 34-ft. deep and some 30 miles long in the estuary of the Cape Fear River (which has a length of about 250 miles and thus is comparable with the River Thames). The extent to which these dredged channels are self-maintaining is not disclosed, but at Wilmington, although the mean tidal range is only 3.36-ft., the extreme range is about 6.5-ft., both at the port and at the ocean bars, while there is a strong flood tide and an ebb tide with a velocity of about three knots.

The extent and design of the transit sheds and warehouses, which, due in part perhaps to the ample space available, are single storey, are worthy of note, as is also the design of the wharf, the apron of which is 43-ft. wide, and of the cavity type, with surfaced selected filling, which not only saves concrete but also provides a heavy deck system.

Jurisdiction over the Ports of Wilmington and Morehead City is vested in the State of North Carolina and it will be observed that this power is exercised by the State over any other ports which may be deemed necessary for waterborne commerce, which with the control of the American Legislature over all maritime works and facilities represents an important method of port administration in the United States. It will also be observed that the new North Carolina Port Authority is still in competition with other port terminals at Wilmington and elsewhere which are owned by various railroads, but we are not informed whether any co-ordination exists between the competing interests regarding the scale of charges for port and dock dues. The trade and future prosperity of both Wilmington and Morehead City would seem in any case to be well assured. however, having regard to their encouraging export and import possibilities.

Coastal Engineering.

There are no more tantalizing problems in nature than those presented by sea action at, and near, the coastal boundaries of the wide oceans. They are complex problems enfolding all the irregularities of unconfined and frequently unpredictable phenomena. To analyse or separate the one feature from the other has its difficulties, as the characteristics of the whole are so variable and interdependent that cause and effect become elusive. Recognising the value of the interchange of information and ideas, the Council of Wave Research of the University of California in collaboration with the Scripps Institution of Oceanography, the American Geophysical Union, the Army Corps of Engineers, the Hydrographic Office of the U.S.A. Navy, the Beach Erosion Board, and several other important bodies, has inaugurated an annual conference to discuss these matters.

The first meeting took place at Long Beach, California, in 1950, and thirty-five papers were submitted, six of them dealing with the Basic Principles of Wave Motion, six with Basic Design Data, seven with Coastal Sediment Problems, nine with Site Criteria and the Design and Construction of Coastal Works and seven with the Case Histories of Coastal Projects. These papers have just been issued in book form under the title of " Coastal Engineering." As would be expected, such a varied selection of papers contains much that is interesting, instructive, and of great practical use. We are therefore fortunate to obtain permission from the above Authorities to reprint for the benefit of our readers, selections of the papers, the first of which, " Elements of Wave Theory " by R. L. Wiegel and J. W. Johnson appears on page 15 of this issue.

The large number of the papers in the book, with little or no duplication, show the scope of the subject matter comprised in the title. Indeed, problems of beach erosion, protection, silting, and amenity structures, require for efficient solution a knowledge of wind and wave mechanism and effects, currents, tides, morphology of the coast, hydrography of the littoral, the character and quantity of littoral mobile material, the feeding sources in the zone, and the influence of man-made structures on the beach regimen. It is realised today that such fundamental knowledge is a pre-requisite to successful operations, but in times past, disregard of such matters has resulted in the worsening of conditions by ill-advised interference with natural phenomena.

As Messrs. Wiegel and Johnson point out in their paper, the theoretical approach is tempered to the useful end, and although the classical theories have been founded on assumptions not rigorously applicable to actual sea waves, they have been proved to be as near as we can get to express the mathematical mechanism of the jumbled seas about our coasts. The support for the Stokes Wave theory is interesting, as it shows the trend of scientific theory to become more practical minded, meshing in with the needs of the engineer. The intensive study and experimental investigation of

Editorial Comments—continued

the diffraction and refraction of waves over a wide stretch of the littoral is bringing to light many of the troublesome features of complicated wave mechanism and wave manufactured currents.

It is interesting to note that the Wave Research Council had a further successful meeting in Houston, U.S.A. in November last, and we hope in due course to be favoured with similar facilities to reprint a selection of the papers which were read at that meeting.

The St. Lawrence Seaway.

Towards the middle of last month, a conference was held in Washington, U.S.A., when initiation of work on the power scheme in connection with the St. Lawrence Seaway and Power Project was discussed between President Truman and United States and Canadian officials.

As has already been pointed out in these columns, American co-operation in the power phase is necessary because, under the Boundary Waters Treaty of 1909, a joint United States-Canadian Commission was established to review any proposals which might alter the level or flow of the St. Lawrence River and other boundary waters. At the conference referred to above, Mr. Truman agreed to the immediate submission of the all-Canadian project to this Joint Commission, without prejudice to any action which might be taken later by the American Congress to make the international waterway project possible on the basis of the 1941 agreement made between the two countries.

It will be remembered that the Canadian House of Commons recently passed a Bill authorising the Government to proceed with the building of the Seaway, whether the United States agrees to co-operate in the project or not.

Meanwhile, the latest reports available at the time of going to press, indicate that the U.S. Senate Foreign Relations Committee, debating the St. Lawrence Seaway and Power Project, has voted to report back to the Senate for further consideration. A move to report favourably, only just failed on an equal vote of six for and six against the proposal. The Senate will now have the opportunity to debate plans for the joint construction of the Seaway in co-operation with Canada, but it is understood that the chances of approval being given by the U.S.A. to the Seaway part of the project are still considered to be remote.

Continuing Problem of Cargo Pilferage.

The Liverpool Underwriters' Association, in their 150th Report which was issued early last March, expresses concern at the serious position regarding cargo pilferage at ports. This subject has frequently been referred to in these columns, and unfortunately, it seems that the world-wide problem of suppressing the evil is as far from solution as ever.

According to the Report referred to above, it appears that, during the early part of last year, there were indications that losses on the Merseyside were becoming a little less serious, but towards the end of the year, the position again deteriorated, due, in some measure, to the further increase in the cost of consumer goods which are in short supply as the result of strategic stockpiling and the rearmament programme.

Congestion at ports resulting from shortage of labour and out-of-date cargo handling equipment renders the problem of prevention more serious and one of the most disturbing features has been the number of highly organised thefts of large quantities of cargo from warehouses.

The Liverpool police report that, during the twelve months from October, 1950, to 1951, the reported number of thefts of cargo was 650, compared with 524 in the previous year. The increase in the number of cases at the dock estate in Birkenhead was even more alarming, the totals being 50 and 163 respectively. One encouraging feature, however, has been the success obtained from the improved methods of co-operation with the Mersey Docks and Harbour Board and the new system of detection employed by the police, which has enabled no less than 78% of the thefts to be detected.

Where foreign ports are concerned, the Report states that information from abroad also is far from encouraging; to take only one example, a report was made towards the end of last year by an agent of the Federal Bureau of Investigation in New York, stating that the amount of theft and pilferage on the New York waterfront had now become intolerable. A proposal has also come from New York that manufacturers should adopt the use of secret identification marks for valuable cargoes. This suggestion, incidentally, was put forward by the Liverpool Underwriters' Association in their report for 1948.

Col. A. C. Tod, C.B.E., chairman of Elder Dempster Lines Holdings, Ltd., recently stated that his Company's losses from theft and pilferage continue to increase in spite of the elaborate and expensive precautionary measures taken. He pointed out that during 1951 no less than 148 persons were convicted by courts, at home and abroad, for thefts of cargo in the Company's custody, and added that they cannot expect a satisfactory end to their pilferage problem while the rewards for successful stealing are so great and the penalties on detection relatively so small.

This seems to be the crux of the position, and some sterner sentence than merely imposing a small fine or a short term of imprisonment is clearly required. It is certainly time that more drastic steps were taken to eradicate an evil which shows little sign of decreasing.

Gantry Cranes Expedite Cargo Handling.

In view of the controversy which has been freely ventilated for many years past concerning the speed and efficiency of cargo handling by quay cranes compared with ship's gear, it is interesting to observe that in the February, 1952, issue of "World Ports," the official organ of the American Association of Port Authorities, it is stated that the extensive use of gantry cranes at the Seattle Port of Embarkation has been largely responsible for speedy and efficient cargo loading and unloading operations.

The port has four full-arch gantry cranes which move the length of the piers on rails, and are used to load vehicles and other heavy freight from the dock, rail cars, or barge directly to ship. The majority of the lifts are five tons or less, and it has been found that vehicles can be loaded faster and with greater safety by crane than with ship's gear, as the crane can expeditiously spot vehicles in the square of any hatch with precision accuracy. In handling lifts from barges gantry cranes can reach across a ship to make a lift, and they also can move on their tracks along the pier, take a lift from a flatcar and travel with it to the proper hatch and lower it into the ship's hold.

An example of how the speed and flexibility of cranes save time and money was shown in a recent barge loading operation. Several flatcar loads of 80-ft. steel sheet piles arrived at the Port of Seattle, and by running the cars under the crane, the piles were lifted 15 to 20 at a time and placed on the barges. It is estimated that the crane unloaded the cars in one-tenth of the time required to handle them by any other means, so that labour costs were appreciably reduced and the rail equipment was freed sooner

Trent Navigation Improvement.

A large modern lock at Newark, built by the Docks and Inland Waterways Executive to facilitate the movement of traffic on the Trent Navigation between the Humber and Nottingham area, was officially opened last month.

The new lock is 192-ft. 10-in. in length, 30-ft. 2-in. wide, with a depth of water 8-ft. 6-in. It will be able to pass in one operation a unit of four standard Trent craft carrying about 500 tons, or a large single craft of 200 to 250 tons capacity, according to the type of cargo. The old lock could deal only with single craft of the standard Trent type, but the new lock will enable the larger craft, including an increasing number of oil tankers, to extend operations up to Colwick. Later, when certain other work has been carried out, they will be able to reach Nottingham.

The opening of the new lock marks the virtual completion of an ambitious plan authorised in the Trent Navigation Act of 1906. Speaking at a luncheon following the opening ceremony, Sir Reginald Hill, chairman of the Executive, said that, subject to reasonable traffic being forthcoming, the expenditure at Newark should prove to be profitable. Interest in waterways was beginning to revive and the project just completed was the first major improvement on the waterways since the war and was the answer to those who would write off inland water transport.

In a forthcoming issue, we hope to publish an article describing the technical features of the new works.

The Ports of Wilmington and Morehead City

Two Modern Seaports of North Carolina, U.S.A.

(Specially Contributed)

FOR some years past, the State of North Carolina has been engaged in building modern port terminals at Wilmington and Morehead City, in an endeavour to regain some of the substantial waterborne commerce it once enjoyed. The present development of the two new ports is the realisation of an idea originating over thirty years ago.

The necessity for greater facilities to handle the growing industrial output of the State of North Carolina and adjacent territories was realised as far back as 1920, but political and other reasons prevented the construction of State ports at that time. It was not until 1945 that the State Legislature of North Carolina passed an Act creating a body known as the North Carolina State Ports Authority consisting of eight (later increased to nine) members appointed by the Governor. The Act was drawn to give the Authority wide powers to develop and improve the harbours or seaports at Wilmington, Morehead City and Southport, North Carolina, and such other places as they may deem necessary, for the more expeditious and efficient handling of waterborne commerce to and from any part of the State of North Carolina and other states and foreign countries.

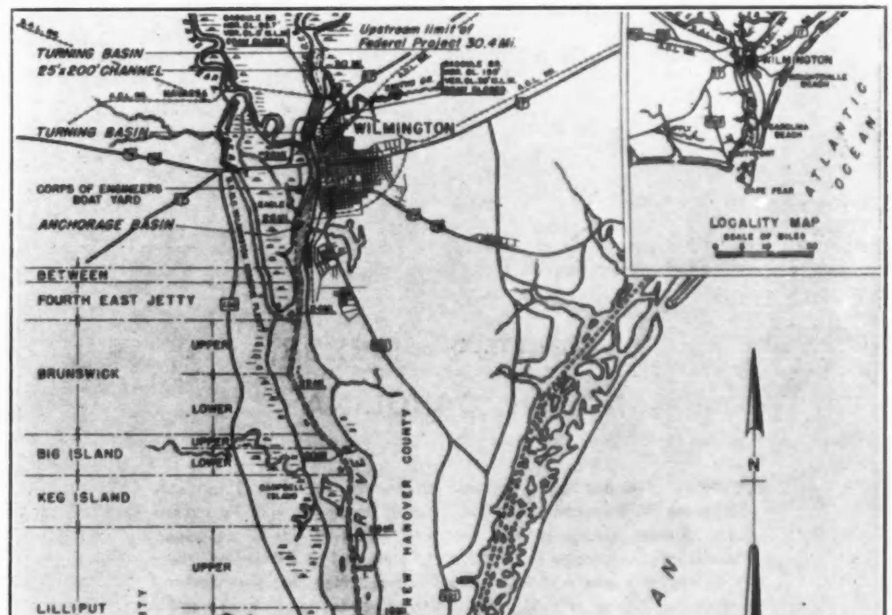
No funds were at first made available to the new Authority, but in 1947, the Legislature appropriated $100,000 for administrative expenses in connection with the preparation of an overall plan of development. Robert & Company, Atlanta and Washington, D.C., engineers, were thereupon employed to make a comprehensive survey of the port's potentials, and two years later, following a thorough investigation into the physical problems involved, their Report was issued; this recommended that modern port facilities be developed at Wilmington and Morehead City, and that a system of secondary, or feeder, ports be developed, utilising the Intercoastal waterway canal that winds the length of North Carolina's irregular and shallow coastline. The Robert Report also recommended that the State take over the physical properties of the Morehead City Port Commission on Bogue Sound, and that the State lease or purchase from the Federal Government all or a portion of, the Maritime Commission property at Wilmington where, during the war, the Federal Government had constructed a large shipyard for the building of Liberty Ships.

After further negotiations had been conducted by the Port Authority, the State Legislature, in 1949, made available, by the sale of State bonds, seven and a half million dollars for the construction of State Ports at Wilmington and Morehead City in accordance with the preliminary plans which had been made.

The composition of the Port Authority is varied and interesting. Its members are appointed for four-year terms by the Governor of the State, and meet when asked by the Chairman or Executive Director, usually once a quarter, interim matters requiring action or decision being delegated to an executive committee.

At both Morehead and Wilmington, the State Port Authority has ample land for expansion, though no immediate plans in that direction are contemplated.

Morehead City is 90 miles north of Wilmington, a fact which has raised some question as to the soundness of the State's policy of developing two about-equal facilities for water-borne commerce. Factors which influenced the decision were that the concentration of the entire programme at Wilmington — or alternatively Morehead



The Ports of Wilmington and Morehead City—continued

Artist's impression of completed facilities at Port of Wilmington.

City—would have had an adverse economic effect upon the other port. The Morehead facility, developed and financed by the City of Morehead, has never paid its way, and the local Port Commission has experienced great difficulty in handling its $400,000 bond issue. Had the State of North Carolina developed state terminals exclusively at Wilmington, the Morehead project would have been in immediate danger of bankruptcy.

On the other hand, if the State had concentrated solely on the Port of Morehead, serious objection undoubtedly would have been forthcoming from Wilmington private terminal and railroad interests. A compromise programme was, therefore, indicated for political as well as economic reasons, and under the programme which has been agreed, neither city is favoured over the other. As a matter of fact, there is ample business for both ports, and for private operators as well. North Carolina is the world's major producer of bright leaf tobaccos, and about one-half of the United States' cigarette tobacco is grown in the eastern half of North Carolina. Wilmington and Morehead terminals are, therefore, certain to get a large share of the industry's export business on account of their proximity to the tobacco growing areas. North Carolina is also expanding rapidly as an important industrial region. The cheap electric power, which is available, has already attracted many new industries, the products from which will comprise an important percentage of the exports.

On the import side, both ports expect a substantial business in foreign tobaccos destined for the cigarette industry in Durham, Reidsville and Winston-Salem. Likewise, a considerable trade in imported hardwoods from the Philippines, South America and Central America is expected for the North Carolina cities of High Point and Thomasville, which are situated about 200 miles inland and are important furniture manufacturing centres and major customers of hardwood lumber importers. There are also signs of an appreciable trade in wool, cotton, canned foodstuffs, and the two principal products of the Hawaiian islands, sugar and pineapple.

THE PORT OF WILMINGTON

Early History.

At one time, Wilmington was the principal port of North Carolina engaged in very profitable commerce. That was when cotton was of importance in the Carolinas, and pitch and turpentine were obtained from the pine forests which covered much of the area. Thousands of bales of cotton and a great tonnage of naval stores from the pine forests made Wilmington a port of some importance, although it was never a trading centre in the proportions of Norfolk, which lies some 250 miles to the north.

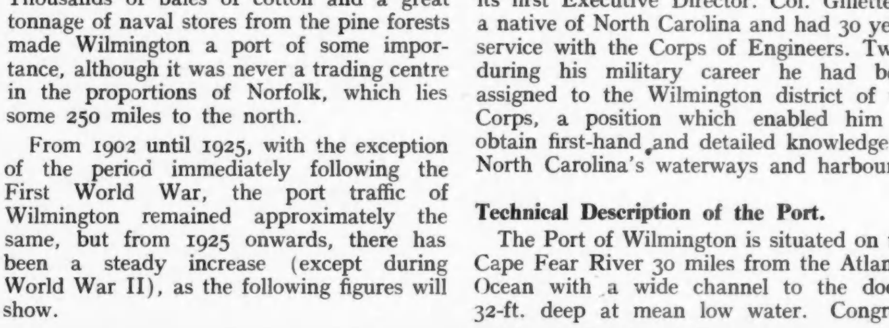
From 1902 until 1925, with the exception of the period immediately following the First World War, the port traffic of Wilmington remained approximately the same, but from 1925 onwards, there has been a steady increase (except during World War II), as the following figures will show.

Year	Short Tons	Year	Short Tons
1902	841,000	1941	2,819,000
1905	871,000	1942	890,000
1910	944,000	1943	649,000
1915	709,000	1944	1,061,000
1920	582,000	1045	1,169,000
1925	1,027,000	1946	2,102,000
1930	1,258,000	1947	2,345,177
1935	1,388,000	1948	2,950,729
1940	2,768,000	1949	3,107,340

In common with many other ports, there was a recession in commerce during the war years 1941-5, and upon the conclusion of hostilities, it was decided that energetic measures were necessary to restore the position, and a systematic campaign was thereupon conducted to stir local interest in the development of the port. This stressed the benefits which would accrue to local industry and agriculture through shorter and less expensive overland freight hauls by use of North Carolina ports. Finally, as already stated, the State Legislature appropriated $100,000 for the Port Authority's operations during the biennium of 1947-49. None of this appropriation was intended for building purposes, but rather for additional surveys and the staffing of the Authority's offices, formally established at Wilmington in the Spring of 1947. One of the first acts of the Authority was to appoint Col. George W. Gillette, a retired U.S. Army Engineer as its first Executive Director. Col. Gillette is a native of North Carolina and had 30 years service with the Corps of Engineers. Twice during his military career he had been assigned to the Wilmington district of the Corps, a position which enabled him to obtain first-hand and detailed knowledge of North Carolina's waterways and harbours.

Technical Description of the Port.

The Port of Wilmington is situated on the Cape Fear River 30 miles from the Atlantic Ocean with a wide channel to the docks 32-ft. deep at mean low water. Congress



Cross-section of Wharf, Port of Wilmington.

The Ports of Wilmington and Morehead City—continued

has recently authorised an increase in the projected depth to 34-ft. at mean low water, plus 2-ft. overdepth together with a widening of the anchorage basin.

In the early summer of 1950, a contract valued at two million dollars was awarded to the Diamond Construction Company of Washington, D.C., for the construction of a marginal wharf, 1,510-ft. long and 200-ft. wide at which three ships will be able to berth simultaneously. The structure consists of approximately 3,000 concrete piles driven to a bearing in hard material approximately 46-ft. below mean low water. These piles support a reinforced concrete deck designed for a loading of 500 pounds per square foot. The deck will also support two railroad tracks and gantry cranes at shipside and transit sheds adjacent to the berths.

The fender system consists of Greenheart piles and timber framing. The pavement is of 8-in. concrete slabs so constructed with load transfer joints as to provide a heavy duty pavement.

Railroad Construction : The apron tracks are 128-lb. girder grooved rail, treated ties; double tongue turnouts with 149-lb. girder guard rails and flush lever boxes. Other tracks are 80-lb. rail, treated ties, ballasted to an average of 5-in. under ties, 2,000 cu. yds. per mile; turnouts, A.R.E.A. Standard No. 8, rigid railbound frog, 11-ft. guard-rail and plates, 16-ft. 6-in. switch, straight split type, with low-type lever boxes.

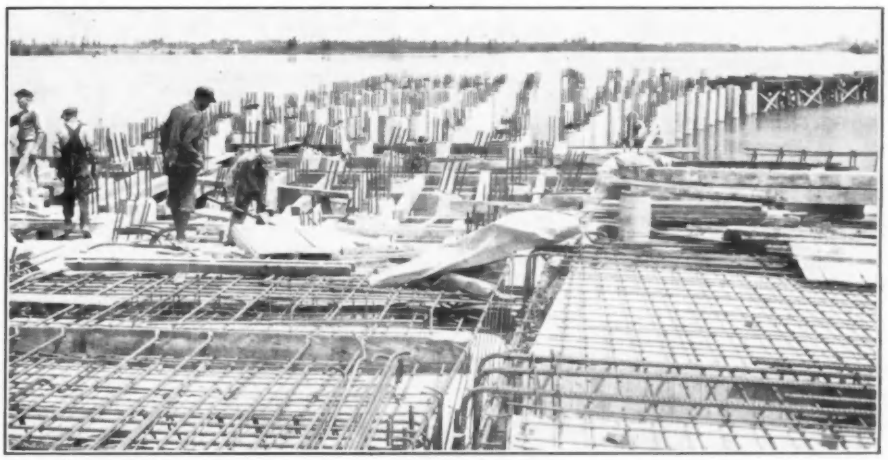
Transit Sheds : Two sheds of 79,000 square feet each have been built on the concrete deck. The roof and sidewall framings are of structural steel, the roof covering being of pre-cast concrete slabs, with a surfacing of two-course tar and gravel construction. The skylights are of corrugated glass, gabled type with ridge vent and damper. The lower 5-ft. of the sidewalls is of reinforced concrete and the upper portion of corrugated galvanised metal. Doors are of the steel rolling type with automatic operation at firewalls only. Firewalls and toilet room enclosures are of concrete and the office side walls of insulated metal panels.

The Storage Warehouse, 98,000 square feet in area is constructed behind the transit sheds and is built on consolidated filling. The retaining walls, column footings and columns are of reinforced concrete and the concrete floor slab rests upon the fill. Structural steel roof framing supports precast concrete roof slabs, and the roofing and skylights are similar to the transit sheds. Exterior walls and firewalls are of concrete. Doors are of the horizontal sliding type except for the truck entrance doors on west elevation, which are of the steel rolling type, with automatic operation only at firewalls.

Fumigating Plant. This will provide four vacuum chambers approximately 6-ft. x 9-ft. long for the fumigation of tobacco, cotton and other commodities requiring such treatment, using the vacuum method. Chambers are designed for a 28-in. vacuum and are of steel plate construction with structural steel stiffeners within the equipment building. This building houses the vacuum pumps, control valves, vaporising equipment, exhaust fans and provides separate rooms for storage of gas masks and chemicals. It is of steel framing with insulated metal sides and roof covering.

The Scale House will be of reinforced concrete construction for the scale pits and floors, with metal covered light steel framing. Motor truck scale to be 50 ton type registering, 45-ft. x 10-ft. platform. Railway track scale will be 75-ton, with a 60-ft. platform, also type registering.

View of Wharf at Wilmington.



Details of reinforced concrete pile construction for Wharf and Apron, Port of Wilmington.

Office and Maintenance Shop facilities will be located in an existing building. This will require remodelling to provide efficient facilities for these purposes, including the installation of adequate plumbing, heating and lighting in addition to new partition construction and other modification.

Fire Protection Systems are provided consisting of adequate water distribution system, outside hydrants including flush hydrants on apron, and complete automatic sprinkler systems (of dry-pipe type) for all buildings.

The Electrical System will include outside distribution, overhead type, street lighting, apron flood-lighting and interior lighting for all structures. Lighting intensities to be provided will be 10 Foot Candles in transit shed and storage warehouse storage areas, 20 Foot Candles on platforms and in toilet areas and 30 Foot Candles in office areas.

The Water System will provide for fire protection, ships' water and other uses, and will be a complete new system, taken from Wilmington's municipal supply, with a 200,000 gallon elevated tank.

Other Miscellaneous Utilities will be largely extensions of existing shipyard facilities. The principal storm drainage work will be an 8-ft. x 10-ft. concrete box culvert at the North boundary of the shipyard to provide for drainage of the railroad yards and access road. The Gantry Cranes will be self-propelled spanning two tracks equipped with 60-ft. booms capable of handling 15 tons at a radius of 40-ft.

The wharf was completed early in September, 1951, and the two transit sheds, the warehouse, and the other auxiliary buildings already referred to, were completed six months later, at a cost of approximately three million dollars.

Trade Returns.

The latest trading figures available show that in 1950 the Port of Wilmington handled nearly 4,000,000 tons of foreign and coastwise imports, mostly sulphur, nitrates and petroleum. Exports, however, exclusive of petroleum handled in bulk on the Cape Fear river, amounted to only 24,500 tons. The totals for 1951, both imports and exports will show an appreciable increase on the above figures.

The Authority's terminals are but one of five such facilities on the Cape Fear River at or near Wilmington. The Atlantic Coast Line railroad owns and operates docks and warehouses, as does the Seaboard Railroad. Other terminals are owned and operated by the Wilmington Terminal Warehouse Company and Heide & Co. These are larger than the railroad-owned terminals, but considerably smaller than those the State has now built.

The Ports of Wilmington and Morehead City—continued

THE PORT OF MOREHEAD CITY

At Morehead City, the State Authority recently acquired, by a special act of the State Legislature in January, 1951, the physical assets of the Morehead City Port Commission, a municipal body first created in 1928, and responsible for the development of a public dock and warehouse on Bogue Sound in 1936-37. The State Authority also paid off and retired some $387,000 in Morehead City Port bonds, including nearly $200,000 of the issue held by the Reconstruction Finance Corporation.

Prior to the development programme at present in hand, the Morehead terminal consisted of a 900-ft. bulkhead-type pier traversed by a single railroad track, and supporting a transit shed-warehouse of 30,000 sq. ft. The enlargement of the facilities involve the extension of a 1,200-ft. bulkhead-type wharf at a right-angle to the existing pier, and the construction of a fireproof transit shed, two fire-proof storage warehouses, with fire protection, electrical and water systems and with railroad and highway connections. Technical construction details are approximately the same as at Wilmington except that instead of resting on concrete pile foundation a steel sheet pile bulkhead will be constructed and filled in.

Artist's impression of completed facilities at Morehead City.

Carr and J. E. Greiner and Company of Durham, North Carolina, and Baltimore, Maryland, designed the project and supervised the construction and the contractor was T. A. Loving and Company of Goldsboro, North Carolina.

Morehead City, which is located on the west bank of the Bogue Sound, is approximately 3½ miles from the sea and has a channel 30-ft. deep at mean low water. U.S. Army Engineers have now completed making a survey of the channel and have approved additional dredging to a depth of 35-ft. with increased widths in the anchorage and turning basins.

At present the State Authority is the only terminal operator, and no private facilities exist other than a small dock owned and used by an oil company for its tank storage plant. The Navy uses the port extensively in connection with operations at the Camp Le Jeune Marine Base and is requesting additional water facilities at this place.

International Hydrographic Conference.

Twenty-seven nations will be represented at the sixth International Hydrographic Conference, which opens at Monaco on May 29 and is expected to last a fortnight. These conferences are held every five years and the delegates of member States are usually headed by the hydrographer of each country. The United Kingdom delegation will be represented by Rear-Admiral A. Day, the Hydrographer of the Navy; Mr. N. Atherton, Chief Civil Hydrographic Officer; and Commander R. H. Kennedy. Since 1921, the work of the conference has been in the hands of the International Hydrographic Bureau, which is a permanent organisation administered by a committee of three directors with a wide experience of practical hydrography.

The Lay-Out of Dock Railways

An Important Adjunct to Efficient Port Working

By HENRY F. CORNICK, M.C., M.I.C.E.

IN THE CASE of a large number of docks, in many countries of the world, their construction preceded that of the railways and, in many instances, owing to the conditions set up thereby, and the limited space available, it has not always been possible to lay out railways in the best and most efficient manner. On the other hand, during the past half century up to 1920, in the United Kingdom, the Dominions and Colonies, and particularly in the United States, a number of ports have been constructed with railways in mind as the principal form of inland transportation.

It is to such ports that one naturally turns one's attention, in the expectation of finding the most efficient layouts for ports largely served by railways, little consideration having been given, at the time of their construction, to road transport, and none possibly to the handling of freight by motor transport. Accordingly, a study of the railway layout of these ports usually provides valuable object lessons for those confronted with the problem of reorganising railway facilities in existing docks, or designing modernisation schemes, or new dock installations.

In modern times, however, increasing attention must be given to providing docks with efficient road layouts as well as railways, to cope with the increasing use of road vehicles for inland freight haulage. It is, in many instances, no mean problem to arrive at a layout which will do justice to both services in existing docks where space is limited.

Whatever general layout is adopted or possible, the functions of dock railways and sidings will be the same, namely to provide areas in which (1) the railway waggons may be exchanged between the main line railway system and the port railways and vice versa, (2) inward bound waggons may be sorted to berth, transit shed or warehouse order, and made up into trains for placing at these destinations within the docks, (3) outward bound railway waggons, i.e., those leaving the docks, may be sorted into train order, or where possible, into marshalling yard order or station order ready for handing over to the main line railway system.

General Layout of Railways.

To fulfil the above broad outline of functions, the railway system of a port must therefore include exchange and classification yards. Their size must be such as to allow the despatch of inward and outward goods, from and to the main line, to an extent at least equal to the handling capacity at the quays from rail to ship and shed, or vice versa. To this duty the main line railway contributes through its own marshalling yard, local goods depot and sidings, and it is then performed consecutively by the main exchange sidings or marshalling yard of the dock system, the district yards and finally the loading tracks at the quays and shed platforms, and vice versa.

The exchange sidings, marshalling yard or holding yard, as they are variously termed, are used for the temporary holding or storage of waggons to be unloaded at the dock, or trains of empty waggons for loading. The classification yards or sorting sidings are used for grouping and sorting incoming waggons in accordance with their dock side destinations, or alternatively, outgoing waggons, in respect to requirements prior to passing them on to the exchange sidings for handing over to the main line railway.

The position and design of these yards is of some importance, for example, the main exchange sidings should be near the railway entrance to the dock, i.e. as near as possible to the main line railway. While the sorting sidings should be located not too far distant from the quays or piers which they serve. In some American ports where the pier system predominates, they are situated at the root of the pier and sometimes between the sheds on the centre line of the pier.

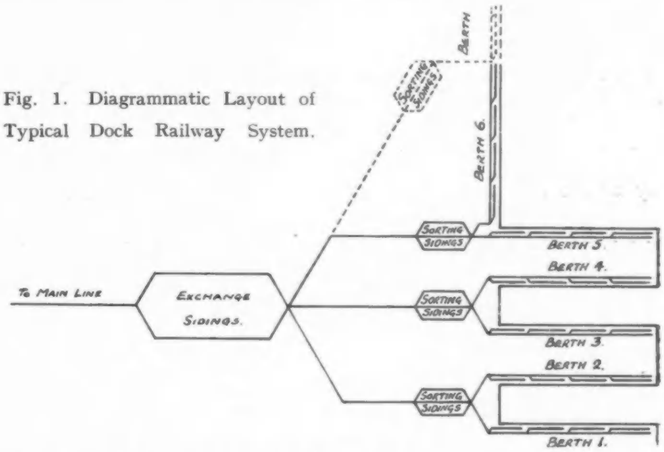
Finally, there are the loading tracks and service or through tracks on the quays and at the rear of the transit sheds, the number provided and layout of which are governed by a number of considerations. Fig. 1 shows in diagrammatic form the layout of a dock railway system.

Railways and roadways must be so arranged and laid out that railway traffic and road traffic interfere with each other as little as possible.

Exchange Sidings.

These sidings are those on which incoming and outgoing trains are exchanged between the State or main line railways and the dock railways and where trains are held pending their being broken down, marshalled and shunted into sorting siding order, governed by their berth or other destination. Many main line railways will only allow their heavy main line locomotives to pass up to a certain point in the exchange sidings of a dock, or it may be over certain agreed sections. The length of exchange sidings depends upon the maximum length of trains running to the docks which may vary considerably according to the situation of the docks, i.e. whether in flat or mountainous country, together with the power of the State or main line railway locomotives.

Fig. 1. Diagrammatic Layout of Typical Dock Railway System.



In normal circumstances in this country, accommodation should be provided for not less than 60-80 normal waggons. The number of tracks which will need to be provided is governed by (1) the maximum number of inward trains likely to arrive; (2) the accommodation at the sorting sidings; (3) the celerity with which waggons can be sorted at the sorting sidings and transferred to the tracks at the quays or other destinations in the docks; (4) the speed at which waggons can be loaded at the quays ex ship or shed, and passed to the sorting sidings. Escape roads should be provided to allow the main line locomotives to be released from the exchange sidings as soon as they have placed their trains, and facilities for supplying water to locomotives should be arranged, accessible to those of the main line railway.

Sorting Sidings.

These sidings are those on which trains from the exchange sidings are broken up into trains of waggons in berth, transit shed, warehouse or other order. Alternatively, it is here that outgoing waggons are sorted into train order and where possible into railway marshalling yard or station order ready for handing over to the main line through the exchange sidings. They are connected with the exchange sidings by through tracks, and tracks known as shunting necks are provided, upon which the actual shunting takes place.

The Lay-Out of Dock Railways—*continued*

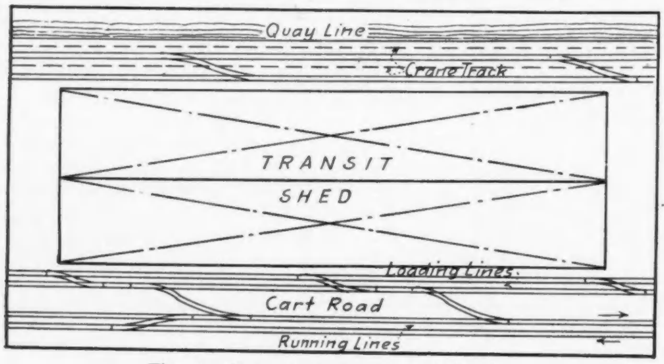


Fig. 2. General arrangement of Tracks.

A very important principle in railway yard working is that waggons should be kept moving in one direction and for this purpose it is desirable that sorting sidings should be situated en route from the quays or berths to the exchange sidings (see Fig. 1). If this ideal layout cannot be attained reverse movements of waggons will occur during shuntng.

The layout of sidings is influenced also by whether they are "flat" or "humped." Flat sidings are most often used in docks where space is usually limited. Where there is sufficient density of traffic and space permits, "gravity" or "humped" yards are increasing in favour and are greatly used in coal exporting docks such as Swansea, Newport, Sunderland, etc., and at many main line goods marshalling yards.

Quay Railway Tracks.

The number and arrangement of tracks on general cargo quays and berths depend upon the importance ot railway freight haulage relative to road transport, and again upon the quantity of goods transferred to ship trom railway waggons and vice versa together with the amount arriving at the transit shed via the railway or the amount of imported goods removed from the transit sheds by railway.

In not many ports is a great proportion of general cargo transferred directly trom railway waggons to ships and vice versa. Normally, the transit sheds on quays are used as temporary reservoirs for the assemblage of outgoing cargo, so that it may be quickly loaded when the ship arrives. Alternatively, the shed is used as temporary storage until the customs and other formalities are concluded and the details of destinations of parcels of imported cargo are agreed with the shippers. In such cases there is little need for a multiplicity of quay side or rear of shed railway tracks. Experience seems to show, however, that two tracks on the quay side and two in rear of the sheds should be provided, one of which in each case serving as a through road or service track.

Where several berths and sheds in a line are concerned and a heavy transfer of goods directly from ship to waggon or vice versa is expected, two quayside tracks may be needed as loading tracks, in which case a third track as a through service track must be provided. In not many instances will it be necessary to provide more than a total of three quayside and two rear of shed rail tracks, i.e. inclusive of service tracks. It must be remembered, however, that multi-storied transit sheds provided with long reach roof or wall cranes may enable two loading tracks to be provided at the rear of the sheds if the quantity of rail borne goods demand them.

On most quays, although normal working may not include direct ship to waggon or vice versa working, nevertheless, provision should be made for rail borne medium heavy pieces of cargo, which are within the capacity of the quay cranes, to be handled direct to or from the ship.

In many docks the tracks in rear of the transit sheds are placed at a lower level than those on the quayside, thus enabling a loading platform to be provided. In the United States depressed tracks are sometimes provided in the sheds themselves especially on "finger" piers; in narrow sheds, however, they take up valuable space, and in many other ways are apt to be detrimental. Where in use in America they no doubt serve the purposes for which they were designed, notably in the railroad terminals.

To obtain the greatest efficiency from quayside railways, there should be a crossover road opposite the centre of each ship's berth and between berths. In regard to the rear tracks, crossovers are preferably placed towards the ends of the sheds. Such arrangements will permit of movement of railway waggons to and from each berth without mutual interference.

Rails on the quays must be "flatted" with the switch lever boxes of the obstructionless type. If road transport is also to be loaded in rear of the sheds at the loading platforms, it will also be necessary to "flat" the rails in rear of the sheds as well. But it is better to arrange for motor vehicles to have access to the sheds at their ends or to have platforms there with road transport areas at the ends of the sheds with access from a road in rear. There are, of course, many special layouts of rails and roads in rear of multi-storied sheds enabling loading platforms for road vehicles to be quite separate from similar railway facilities.

Figs. 2, 3 and 4 illustrate respectively a transit shed and quay layout of railways and roads at Tilbury Docks, Essex; a similar layout, with the addition of a warehouse, in the German port of Bremen; and also the layout of the improvements recently completed at the Charles Malan Quay at Port Elizabeth, South Africa.

Weights and Sections of Rails.

In the majority of docks in the United Kingdom, main line locomotives and passenger railway stock do not run over the dock railway systems except in special circumstances. A notable exception is Southampton, which being a passenger port, railway coaches pass regularly into or alongside quay sheds, and to the passenger terminal. In general, therefore, the usual main line standards of perfection are unnecessary in docks, neither are the same sections used or weights of rails needed, although permanent way railway practice is usually followed in track layout and design.

From the point, by agreement with the State railway authorities, beyond which the main line locomotives, which are much heavier than dock shunting locomotives, do not, as a rule pass, the dock system of railway tracks is almost universally composed of Flat Bottom Rails. Incidentally, it may be remarked that the use, on State and other main line railways, of bull-head rails has been practically confined to permanent way in the United Kingdom for nearly 100 years, but that following experiments commenced in 1936 by Mr. W. K. Wallace, C.B.E., M.I.C.E., then Chief Engineer of the London Midland and Scottish Railway, the use of Flat Bottom Rails was re-introduced experimentally by that railway on several miles of track and later by the other three Railway Companies. A good deal of information in respect of the effects of different weights and types of traffic moving at various speeds over the 110 lb. F.B. Rail used, the advantages of different types of base plates, rail joints and fastenings, depths of ballast and so on, was collected prior to the nationalisation of the British Railways.

As a result, early in 1949, the British Transport Commission was able to approve a recommendation of the Railway Executive to adopt flat bottom rails as the future standard for British Railways.

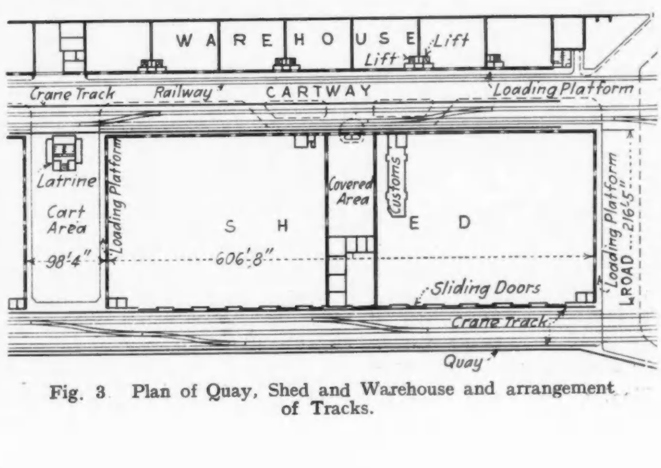


Fig. 3 Plan of Quay, Shed and Warehouse and arrangement of Tracks.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The Lay-Out of Dock Railways—continued

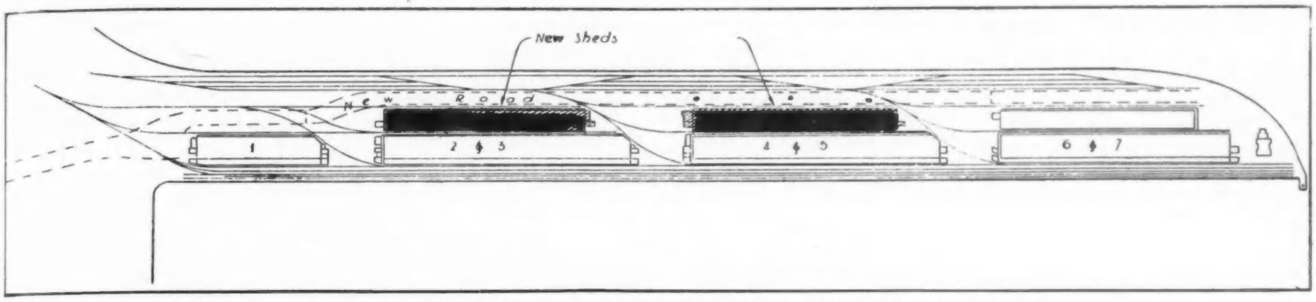


Fig. 4. General arrangement of Railway Tracks, Roads and Sheds, Charl Malan Quay, Port Elizabeth.

Two sections of rails have been designed—109 lbs. per yard for heavy and fast traffic routes and 98 lbs. per yard for less important tracks, over which traffic is lighter and slower. It is probable, however, that finality may not yet have been reached as regards the types of fastenings now in use on the new main line track, and any improvements effected may well be reflected in the fastenings and methods employed on dock railways.

A few words as to the reasons why a return, on main line railways, to the Flat Bottom Rail may not be out of place here, as it may dispel the impression one sometimes hears expressed that there is something inferior in the Flat Bottom Rail system, as used in docks, which may have arisen, possibly by implication, from the claim that the United Kingdom railway track, composed of Bull-head rails, was the finest in the world.

It is a fact that, a century ago, a flat-bottomed rail was in use in this country, but the rail section used had a narrow flange which, under the increasing size and weight of rolling stock and speeds attained, cut into the sleepers. It is probable that under the less onerous conditions obtaining in docks, this rail was satisfactory, and the Flat Bottom Rail continued in use there, and with improvements in section, its many merits for dock work became recognised.

While it is true that with the Bull-head, British railway tracks achieved for many years a world wide reputation for efficiency, and during two World Wars carried unprecedented weights and density of traffic with equal efficacy, such results were only attained under accentuated difficulties and cost of maintenance. This was due principally to not only increasing traffic density and speeds, but to that of maximum axle loads of both locomotives and rolling stock, and it was early realised that the Bull-head rail lacked the necessary stiffness both vertically and laterally which put heavy loads on the sleepers and resulted in heavy expenditure in labour for ballasting and packing to line and level, a necessity for closer spacing of sleepers on heavily worked stretches of track and upon replacement of worn and broken fittings.

The experiments before alluded to, culminating in the adoption on British Railways of a 109 lb. F.B. Rail for main line track is the result of this line of thought. Practically the 109 lb. Flat Bottom Rail is 59 per cent. stronger vertically and 136 per cent. laterally than the old standard 95 lb. Bull-head rail. While the

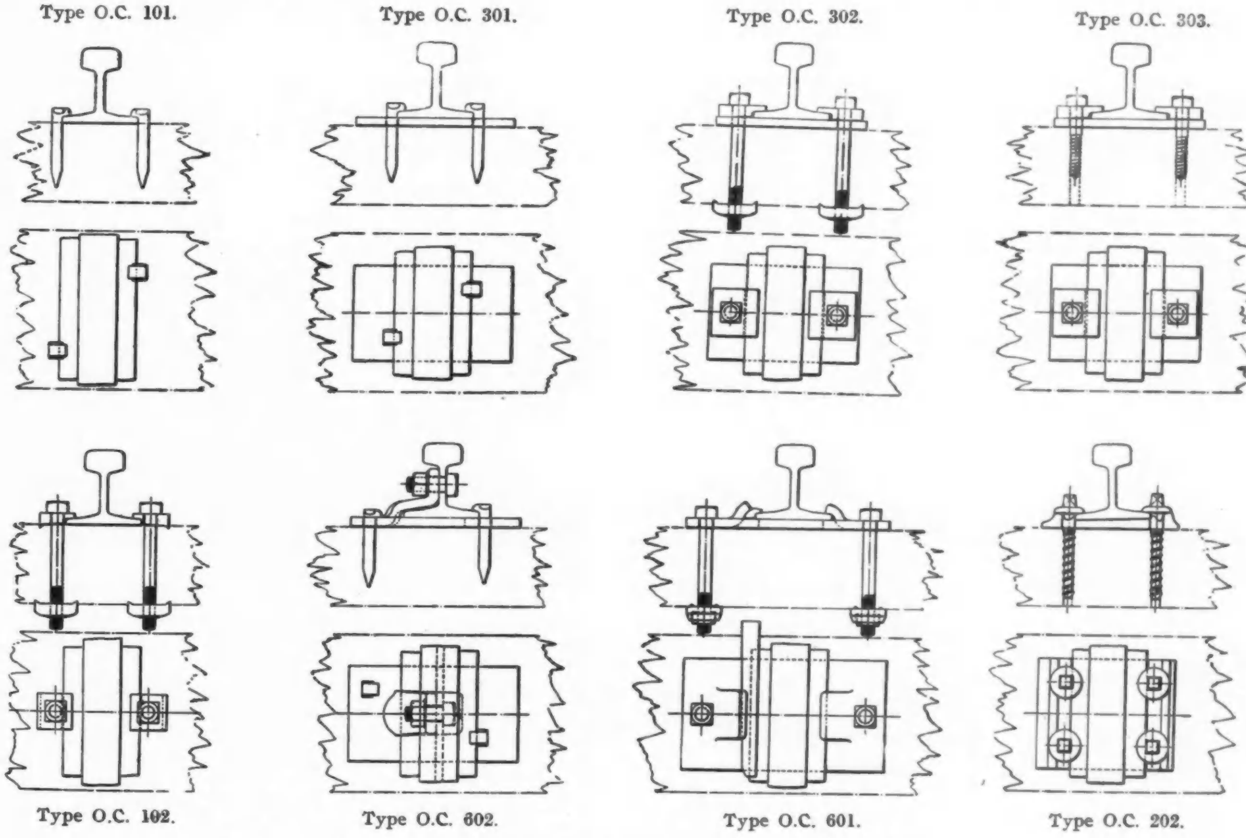


Fig. 5. Types of Single Chairs and Fastenings for F.B. Rails.

The Lay-out of Dock Railways—continued

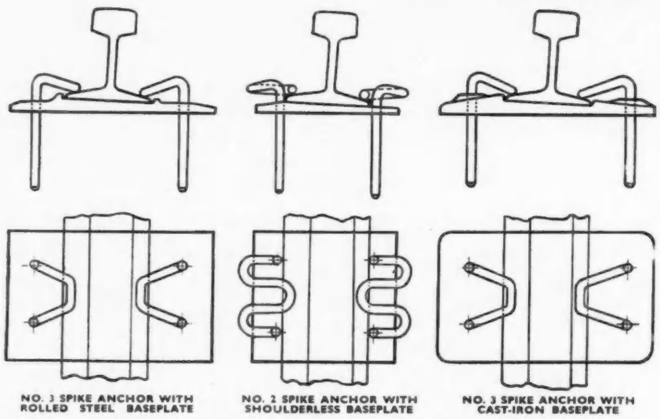


Fig. 6. The Macbeth Patent Spike for F.B. Rails (with or without bearing plates) on timber or concrete sleepers.

cost of the heavier rail is higher, there is yet little data available as to the length of life of the new section of rail on permanent way compared with the older and lighter sections. However, there is direct evidence that there are major savings in other directions. Mr. V. A. M. Robertson, C.B.E., M.C., M.I.C.E. in his Presidential Address in November 1949 to the Institution of Civil Engineers, stated that " each mile of track laid with Flat Bottom Rail requires 16,900 fewer components, including fastenings, thus requiring less inspection and maintenance, with similar stock-keeping and office recording. Moreover, from experience gained, flat-bottomed track, owing to its greater stiffness and weight, requires less maintenance, provided that it is laid over a well drained formation with an adequate depth of ballast . . . The changeover in the standard of permanent way from bull-headed to flat-bottomed track is a major development in railway civil engineering."

From the foregoing remarks it will be seen that there is every justification for the general use of the Flat Bottom Rail system in docks, from both engineering and economic considerations. Moreover, there are other aspects of the F.B. Rail which make it particularly applicable in many special situations that will be referred to later.

The weight of Flat Bottom Rail normally used in the docks of Great Britain varies between 75 lbs. and 95 lbs. per yard in accordance with the special requirements of the various Dock and Harbour Authorities concerned. Below is a list of some of the principal docks and the sections of rails used by them.

	SECTION
Port of London Authority ...	75 lb. F.B.B.S. Rev.
Southampton	75 lb. F.B.B.S. & 90 lb. F.B.
Dover Harbour Board	95 lb. F.B. & 75 lb. F.B.
Tyne Improvement Commission	90 lb. F.B. B.S.
Port of Bristol Authority ...	90 lb. F.B. & 75 lb. F.B.
Ipswich Dock Commission ...	85 lb. F.B. B.S. Rev.
Mersey Docks & Harbour Board	90 lb. F.B.
River Wear Commissioners ...	75 lb. F.B.
Tees Conservancy Commissioners	75 lb. F.B. & 98 lb. F.B.
Admiralty—Invergordon ...	75 lb. F.B.
Admiralty—Portsmouth ...	75 lb. & 80 lb. F.B.

The exact dimensions of the cross-section of each weight of rail are laid down by the British Standards Institution. Classification revisions were made in 1922 and to differentiate between the new specifications and those that remained unaltered the former are designated B.S.(R) and the latter simply B.S. The two current British Standard Specifications covering rails are B.S.9, 1935 Bull-head Railway Rails and B.S.11, 1935 Flat Bottom Railway Rails.

The specifications lay down in detail the composition and sizes of all sections of rail in each category, and perusal of the specifications demonstrates the meticulous attention given to every detail of manufacture which ensures that safety and long service which has made British rails a standard by which rails all over the world are judged.

The following table is reproduced by permission of the British Engineering Standards Association, and shows the main particulars of British Standard Flat Bottom Rails.

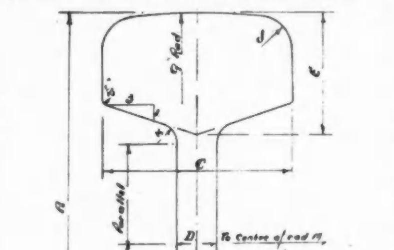
To this table has been added the particulars of the 109 lb. rail of the British Railways.

Besides the Flat Bottom Rail, there is another section of rail which is sometimes used on internal railway systems where tracks or crossings have to be laid and the road levelled for vehicular traffic. This rail is the 126.2 lbs. section of tramway type section. It is compact and saves provision for a separate check rail, the fittings of which, unless carefully thought out and constructed, have a tendency to work loose and, by rising, disturb the road surfaces. On the other hand the weight of the rail may be in excess of the F.B. rail and guard rail normally used, except where the heavier sections are laid whereas there does not seem to be any great increase in wearing properties. However, the tram rail has been successful in its original application in public highways and may well be so in the somewhat different circumstances in docks and special cases elsewhere where it is employed.

Fastenings.

Where Flat Bottom Rails are laid directly on wood sleepers, even though the flange is wider nowadays, there is still a tendency for the rail to compress the timber, which results in a gradual widening of the gauge and canting of the rail outwards which tendency increases with traffic density.

In all first-class work, therefore, or where heavy traffic is prevalent and F.B. rails are laid on timber sleepers, the rails should be fitted with mild steel bearing plates to aid in distributing the load. These plates are made from universal rolled steel flats, 7 inches to 9 inches wide, and ½ inch to ¾ inch thick (the size used depending upon the load carried and weight of rail) and are held to the rail flanges either by rivets or by flange clips. The latter are usually about 3 inches wide, from ⅞ inches to 1 inch thick, and are shaped to fit over the rail flange. They are made either from rolled steel bar of the required section, or as drop forgings or malleable iron castings. Flange clips may be used with bearing plates, whether the track is laid on wooden sleepers or on concrete.



If the former, they are holed to take either fang bolts or coachscrews, and if the latter, rag bolts.

If bearing plates are not used, that is to say on tracks of secondary importance, the outsides of the rails should be double spiked. On all curves of a radius of 7 chains or less, however, bearing plates are desirable.

The former practice of fastening Flat Bottom Rails to wooden sleepers by means of dog spikes impinging on the rail flanges, is being gradually

B.S. No. & nominal weight	A	B	C	D	E	F	G	H	J	K	L	M
lb/yd	in	in	in	in	in	in	in	in	in	in	in	in
25R	2 7/8	2 3/4	1 1/2	1/4	29/32	7/16	1 13/64	1/16	5/16	3/16	1/4	7 1/2
30R	3 1/3	3	1 5/8	19/64	1	15/32	1 19/64	..	..	..	..	..
35R	3 3/8	3 1/4	1 3/4	21/64	1 3/32	1/2	1 25/64	..	..	..	..	..
40R	3 5/8	3 1/2	1 7/8	23/64	1 9/64	17/32	1 33/64	..	3/8	7/32	11/32	9
45R	3 7/8	3 3/4	1 31/32	3/8	1 7/32	9/16	1 39/64	..	..	..	..	..
50R	4 1/8	3 15/16	2 1/16	25/64	1 19/64	19/32	1 23/32	5/32	..	..	..	..
55R	4 5/16	4 1/8	2 5/32	27/64	1 11/32	5/8	1 51/64	..	..	..	..	..
60R	4 1/2	4 5/16	2 1/4	7/16	1 13/32	21/32	1 7/8	..	..	..	..	..
65R	4 11/16	4 7/16	2 5/16	15/32	1 29/64	11/16	1 31/32	..	7/16	1/4	3/8	12
70R	4 7/8	4 5/8	2 3/8	1/2	1 1/2	23/32	2 3/64	..	..	..	..	..
75R	5 1/16	4 13/16	2 7/16	33/64	1 9/16	47/64	2 1/8	3/16	..	..	..	..
80R	5 1/4	5	2 1/2	17/32	1 39/64	49/64	2 13/64	..	..	5/16	..	..
85R	5 7/16	5 3/16	2 9/16	35/64	1 43/64	25/32	2 9/32	..	..	..	..	..
90R	5 5/8	5 3/8	2 5/8	35/64	1 23/32	13/16	2 23/64	..	1/2	3/8	..	15
95R	5 13/16	5 9/16	2 11/16	9/16	1 25/32	53/64	2 7/16	..	..	..	..	..
100R	6	5 3/4	2 3/4	9/16	1 27/32	27/32	2 1/2	7/32	..	..	..	..
105R	6 1/8	5 7/8	2 13/16	37/64	1 57/64	7/8	2 9/16	..	..	..	..	..
109R	6 1/4	5 1/2	2 3/4	5/8	1 15/16	13/16	2 9/16	1/8	..	7/16	5/8	..
110R	6 1/4	6	2 7/8	19/32	1 29/32	29/32	2 5/8	7/32	9/16	3/8	3/8	..
115R	6 3/8	6 1/8	2 15/16	39/64	1 15/16	15/16	2 11/16	..	..	..	..	..
120R	6 1/2	6 1/2	3	5/8	1 63/64	61/64	2 47/64	..	..	..	..	..

The Lay-out of Dock Railways—continued

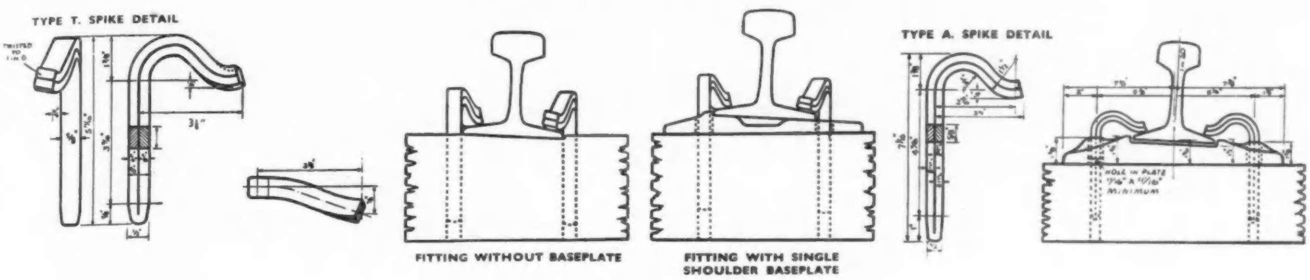


Fig. 7. Elastic Rail Spikes.

replaced by the use of flange clips with coachscrews or fang bolts. Within the last few years, however, British Railways have adopted the practice of laying Flat Bottom Rails on canted bearing plates (canted 1 in 20), which are fastened to the sleepers either by "elastic" spikes, by the "Macbeth" two-prong spike, or by spring steel clips and tee-headed bolts recessed into the chairs with independent holding down coachscrews.

Fig. 5 illustrates the principal types for chairs and fastenings for F.B. rails. There are other forms of spikes such as those with jagged edges and twisted shanks, but it is doubtful whether any advantage is secured by their use. Two well-known forms of flexible steel spike are the "Macbeth" patent spike and the "Elastic" spike, these being shown in Figs. 6 and 7. The latter is the original rail fastening designed to absorb vertical rail movement so that such rail movement does not withdraw the Spike shaft from the sleeper. The head of the Spike flexes under wave motion of the rail and constantly maintains pressure on the rail base; rail creep is thus resisted in either direction. The Spike is laminated in order to give ample flexibility with low stress.

The Spike is made from one piece of silico-manganese steel bar, suitably formed to give a laminated shaft and head $\frac{5}{8}$-in. square, then hardened and tempered. It is driven until the head of the Spike makes contact with the rail foot, and thereafter a further amount, normally a maximum of $\frac{3}{16}$-in., which flexes the head of the Spike and puts proportionate pressure on the rail base. When the Spike head is deflected $\frac{3}{16}$-in., a resultant pressure of about 800 lb. is put on the rail base and, since all Spikes are driven a uniform amount, it follows that creep load in either direction is carried equally by all sleepers.

Those for use without base plates or with single shoulder base plates have a twisted head. Equal numbers of right and left hand twisted spikes ensure correct pressure. The straight spike is used with double shouldered base plates—usually six spikes per sleeper.

British Railways are using "Elastic" spikes with rolled steel or cast iron base plates on those sections of track which are being relaid with the now standard flat bottom rail, and they are being adopted by many dock and industrial undertakings. They are also used by railways in Africa, Australia, New Zealand, South America and on the continent of Europe. The principle makers of the "Elastic" spike are the Elastic Rail Spike Co. Ltd., London, Messrs. Thos. Summerson and Sons, Ltd., Darlington, and Messrs. Thos. W. Ward Ltd., Sheffield.

(to be continued)

Pneumatic Breakwaters

By A. H. LAURIE, M.A.

(Formerly Assistant Scientific Officer, Royal Research Ship *Discovery II*)

In the year 1906 an American, Philip Brasher, had occasion to travel frequently by ferry between New York and Long Island. Tunnelling operations were in progress, and he was struck by the appearance of air bubbles in large quantities escaping from the workings and rising to the surface of the water. The effect which most intrigued him was that, where the bubbles came to the surface, there was a marked reduction in the height of waves and swell. It was not long before Brasher began to put his observations to good use, and U.S. Patent No. 843926 of 1907 in his name contains a specification for "Protecting Objects from Water Waves" by means of a controlled flow of compressed air from a submerged pipeline. The essence of the idea was that the interposition of compressible matter, in the form of air bubbles, would serve to dissipate the kinetic energy in the water particles of a wave of oscillation. As will be shown below it is probable that undue emphasis was placed on the function of bubbles as compressible "cushions"; however, the first installation along these lines, for the Standard Oil Co. of California, appears to have been a success.

The object of the installation was to protect an oiling jetty at El Segundo, near San Pedro, which had already suffered storm damage. A pipeline 320-ft. long by 4-in. diameter was laid on the sea bed off the end of the jetty in a depth of 30-ft. The pipe carried nozzles $\frac{1}{2}$-in. diameter at 6-in. centres, and was connected to a pair of compressors each rated at 1,000 c.f. per min. (free) and located at a distance of two miles. A contemporary account (Compressed Air Magazine, May, 1916) gives the probable output at the nozzles as not more than 1,500 c.f./min. The same source tells of the behaviour of the apparatus during a storm in the winter of 1915-16 when 12-15-ft. waves approaching the jetty collapsed on reaching the zone of bubbles.

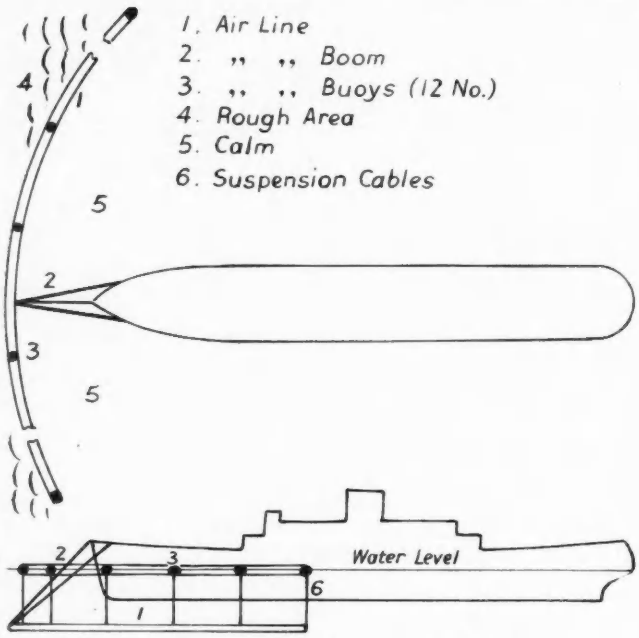
Some space has been given to a description of Brasher's installation because it appears to be the only one which was successful, and which demonstrated the feasibility of the process. Other trials were made on the Atlantic Seaboard which seem to have been inconclusive and the enterprise appears to have foundered.

The present writer, having conceived the same idea from a different standpoint, has been at some pains to determine the reasons both for the success of the Californian installation and for the failure of other projects both in America and in other parts of the world where the subjugation of waves by means of compressed air has been attempted. As a result it appears that the design of a satisfactory and economical breakwater hinges on (1) efficient compression and distribution of air, (2) an appreciation of the function of the air in breaking down wave motion, and (3) an understanding of the nature of wave motion inshore and of limiting factors which determine the location of the airline.

A simple calculation shows that the bubbles as such play a small part in providing compressible cushions in the path of wave motion. Bubbles emitted from the half-inch nozzles of the Californian prototype had a diameter of approximately 4-in., and it is unlikely that individual bubbles were formed so much as a continuous column of air from jet to surface, travelling at high velocity. Since it is not easy to assess the behaviour of the air in these conditions, it is more convenient to imagine the same output of air released in the form of small bubbles whose speed of ascent is known.

Suppose the same volume of air, 15 c.f. per yard per min. were discharged as small bubbles which rise from 30-ft. to the surface at a mean velocity of 0.83-ft. per second. The volume of bubbles present at any given moment in still water would be 7.5 per cent. of the zone in which the curtain of bubbles operated.

Pneumatic Breakwaters—continued



Plan and elevation of mobile pneumatic breakwater.

This is, however, an imaginary condition, since the presence of the bubbles reduces the density of the water column resulting in an upward thrust of approximately 1.1 lbs/sq. in. Thus an air lift is created which brings about a vertical and upward movement of the water. Now suppose that acceleration and friction balance each other at a velocity of 3-ft./sec., the volume of air in the column, allowing for the speed of ascent of the bubbles in the rising water, will be about 1.6 per cent. It can hardly be supposed that such a volume of air would present a sufficient surface of compressible material to absorb and dissipate the energy of a wave.

It appears therefore that the principal function of the bubbles is to create an air lift, whereby a steady stream of water is maintained. The destructive effect on waves of a cross current is well known and can be observed where a tidal stream traverses the path of waves in the open sea, or in the wake of a ship, where the turbulence of the slipstream temporarily kills wave motion at the surface. Wave motion can in effect be broken up by a change of velocity in the water which is of the same order as the particle velocity of the wave. Thus it seems that an important element of design concerns the propagation of small air bubbles whose rate of ascent in the moving column of water is slow, leading to the maximum useful "life" of the air before it reaches the surface.

The limiting factor in the placing of a Pneumatic Breakwater concerns the nature of waves. Wave motion in open deep water is the sum of the movement of individual water particles which at the surface describe a circle whose diameter is equal to the height of the wave. The diameter diminishes with depth and is held to be insignificant at about 30-ft. It follows that any device which aims at disrupting wave motion should ideally operate throughout the 30-ft. range. It also follows that where the total depth of the water is less than 30-ft., changes in the nature of wave motion are taking place which on a shelving beach result in conversion from waves of oscillation to wave of translation, and lead ultimately to the wave's breaking.

The nature of the changes in shallow water is too complicated to enlarge upon here, but it may be said that the path and velocity of water particles are modified in such a way as to make them less susceptible of inteference by cross currents of low velocity.

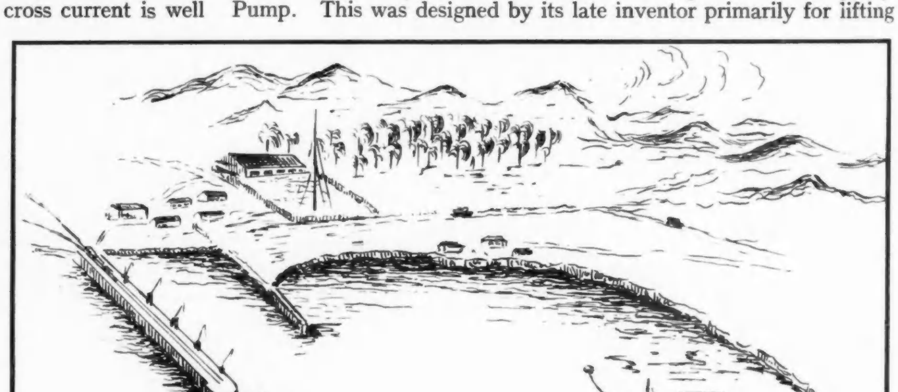
It appears to be no accident that the only successful attempt to reduce waves by compressed air coincided with the placing of the airline at a depth of 30-ft. It is equally likely that other attempts have failed, assuming correct technique and air output, because, so far as the writer can ascertain, they were made in shallow water, or near the mouth of a tapering inlet which would, roughly speaking, create conditions similar to that of shoal water.

To sum up, a Pneumatic Breakwater must provide an efficient air lift, in which the work done in compression is recovered as far as possible in useful water movement throughout at least the top 30-ft. of water, while the Breakwater must not be located inshore of the five fathom line.

The principal elements of design in a modern system now being patented are: the air distributor line is composed of rigid sections with flexible couplings at each end. Each section is arranged to have slight negative buoyancy when delivering air, and is held at the correct depth by suspension from a float, which also serves to mark the position of the Breakwater. The airline is perforated with many small holes to provide a dense curtain of bubbles, the spacing of the holes being such as to allow the bubbles to expand as they rise without coalescing. Moorings are provided for each section and the weight of chain and capacity of the float are adjusted to allow the airline to sink when flooded (i.e. when the compressor is not working) to a convenient depth to allow the passage of ships. Another design, for use in deep water, provides for a free-floating and mobile air line, suspended as before from floats, which by incorporating water lines and an elementary system of jet propulsion can be made to take station in any desired position.

The compressor is unconventional. It must produce large volumes of air at low pressure. The machine must be reliable to a degree, and capable of standing idle for long periods in a marine climate without deterioration. It should be capable of pumping air and a moderate volume of water at the same time for the operation of the free-floating type of Breakwater mentioned above. It should also be simple to start and stop.

In order to satisfy these unusual demands, the design makes use of one of the simplest internal combustion engines, the Humphrey Pump. This was designed by its late inventor primarily for lifting



Artist's impression of pneumatic breakwater protecting an exposed shore.

Pneumatic Breakwaters—continued

water, but, as he himself foresaw, it can be adapted to compress air. These pumps combine the prime mover and pump in one unit, the piston-cum-flywheel is water, and the mechanical efficiency has been rated at 98 per cent. Their thermal efficiency is high, and there are no moving parts except for simple valves. Their rugged construction make them suitable for the duty which is envisaged.

The design aims at using a pump which will produce about 10,000 c.f./min., at 32 lb. A., and advantage will be taken of the fact that their efficiency is much the same at half load as at full load to double the safety factor by providing them in duplicate.

It is anticipated that the principal scope for Pneumatic Breakwaters will be in exposed situations such as open roadsteads, and for this purpose the pumps are mounted in a barge. The barge is moored in the lee of the Breakwater, and need not be designed to carry the considerable deadweight of the pumps when working. The pumps' construction enables them to be lowered into the water and locked in a position where their own buoyancy relieves the barge. Return of the pumps inboard for maintenance, drydocking, etc., is effected by blowing down the contained water when the pumps will rise into the hull.

In cases where the Pneumatic Breakwater supplements existing harbour works the pumps will more economically be housed on land or on a breakwater.

The following uses for Pneumatic Breakwaters are anticipated.

Fixed Installations : Extension of existing breakwaters. Protection of harbour mouth. Temporary protection for harbour construction. Salvage. Improvement of lifeboat launching sites. Provision of landing strips for flying boats. Control of coastal erosion, in which wave control is effected without diversion of tidal streams. Improvement of open anchorages for lighterage. Increased amenity at seaside resorts.

Mobile Floating Types : Protection for stationary ships on specialised work, such as oceanographical and cable vessels, and weather ships. Protective screen operated by a salvage vessel to minimise damage to a stranded or drifting ship.

Cost : The first cost of a Pneumatic Breakwater is expected to vary between £35 and £50 per yard, complete, according to the site. Unlike the conventional breakwater the cost will in the main be independent of depth of water.

Operating costs per hour of actual working will be dominated by local fuel prices. A provisional figure of a halfpenny to three farthings per yard per hour is suggested.

Water Intake for Coryton Oil Refinery

Details of Methods of Construction

IN the successful operation of an oil refinery, one vital factor is adequate cooling water, both for the power station and for the process plant. This problem has been solved in the case of the Coryton Refinery of Vacuum Oil Company Limited by obtaining the necessary water from the nearby Thames Estuary, the structure to house the pumping machinery having been built at Gravesend and Tilbury, after which it was towed for a distance of about eight miles down the Thames to its final position at Coryton. This structure is a large reinforced concrete caisson which rests on a previously prepared bed in the river.

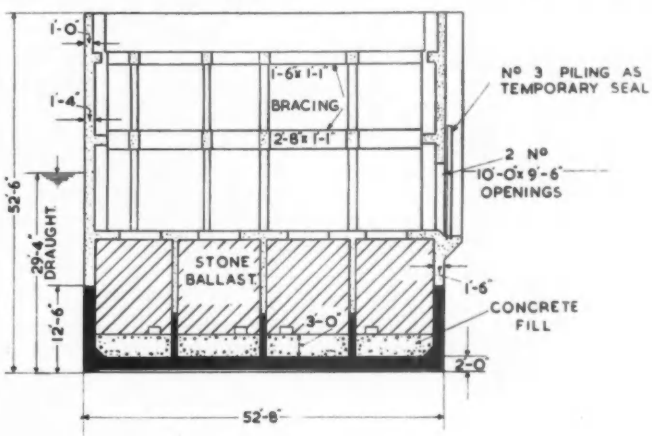
The practice of employing reinforced concrete caissons for various kinds of foundations is, of course, a well-established civil engineering technique, but it is exceptional for such a structure, weighing 4,200 tons, to be towed a long distance from its place of construction to its final site. The design and construction has been carried out by the British firm of Civil Engineering Contractors, John Laing and Son Limited, on behalf of The Lummus Company Limited, of London and New York, the Principal Contractors for the Coryton Refinery.

There is a similarity in the type of construction between the caisson for Coryton and the "Mulberry" Harbour Breakwater Units constructed during the war, and experience gained under the stress and difficulties of wartime conditions has been put to very good use in the solution of a peace-time problem. Alternative designs were carefully considered before selecting the most suitable type of construction. More conventional methods were abandoned for various technical reasons and because of local conditions and the problem of the speedy delivery of essential materials.

For the purpose of construction, it was necessary to find a dry dock in which the bottom portion of the caisson could be constructed to a height governed by the depth of water available, subsequent lifts of concrete being added later in a wet dock.

A dry dock was obtained at Gravesend, which could be adapted to provide a firm base for the structure. This dock is at the Red Lion Wharf and the first stage of the preparatory work was to close its entrance with a ballast-filled sheet piling dam able to withstand the water pressure due to the full tidal range. A level concrete screed was then laid in the bottom of the dock and, following "Pheonix" unit procedure, hollow tiles were placed on this, covered by a layer of building paper, upon which the floor of the caisson was laid. The partially constructed unit was floated off the hollow tile base without any difficulty when water was admitted to the dock at high water of a spring tide.

Concreting of the floor and side walls proceeded in this dock to a height of 12-ft. 6-in., the concrete mixers being located alongside the dock. Eighteen 6-in. valves were built into the lower part of the walls to control the flooding of the unit for ballasting purposes. The caisson was tested for watertightness by filling it with water and waiting for the tide to fall, this being carried out



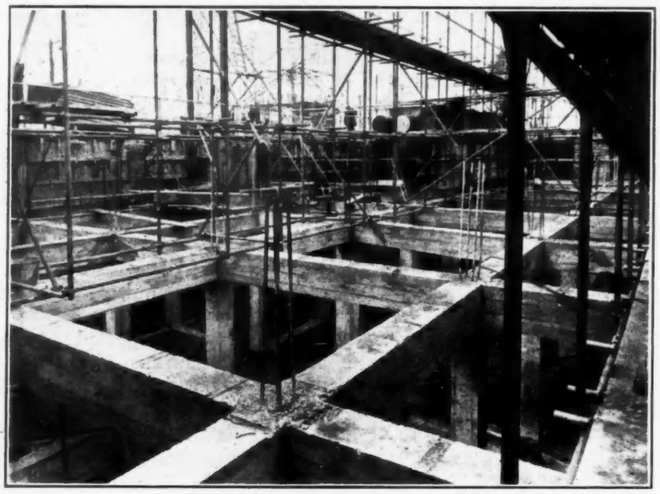
Typical cross-section of unit.

at the stage when the unit had been finished to the 12-ft. 6-in. level and the sheet pile closure dam had been removed. In spite of a month's delay due to steel shortage, the work at Gravesend was completed in four months.

With reference to the accompanying typical section, the lower portion of the caisson which was constructed at Red Lion Wharf, Gravesend has been coloured black.

The structure had an overall length of 100-ft. and a width of 53-ft., and was divided into six main compartments; the external walls were 1-ft. 6-in. thick and there were three longitudinal walls 9-in. thick, and nine transverse walls of the same thickness below the bottom floor slab which was 20-ft. above the base. The total

Water Intake for Coryton Oil Refinery—continued



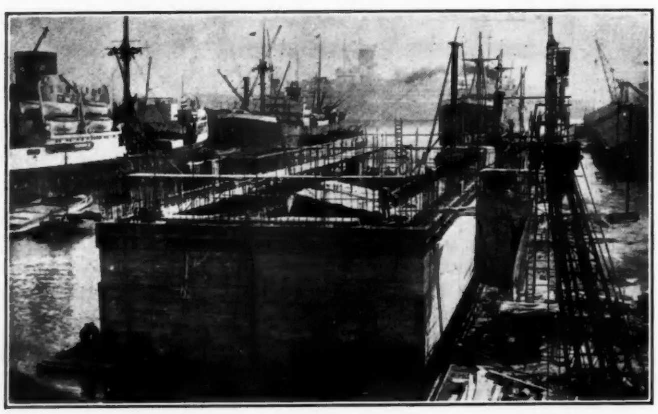
The internal structure of the unit.

height of the unit when it left Tilbury was 52-ft. 6-in., the structure having been erected in lifts of 2-ft. and the final two lifts with the deck were added when the unit was in place at Coryton. It will be noted that there are longitudinal and cross braces 13-in. wide, the lower ones being 32-in. deep and the upper ones having a depth of 18-in.

On November 30, the partially completed unit was towed across the river from Gravesend to Tilbury by three tugs, one on each side and one in front, the structure having been provided with the necessary towing connections. On arrival at the wet dock at Tilbury, where it occupied a liner berth, the unit was surrounded completely with a floating boom to protect it from drifting craft, and the joiners and steel fixers were able to work from this boom, concrete being poured from scaffolding inside the now floating unit. Each lift of concrete in the walls was 2-ft. high, and for the first five lifts the above procedure was adopted. Water ballast was introduced from time to time in order to keep the shuttering within reach of the workmen on the floating boom.

The floating boom was constructed of 12-in. x 12-in. main timbers 3-ft. apart. Forty-gallon oil drums were fixed securely between these timbers and diagonal bracing and timber decking laid on top. The boom floated with about 9-in. of freeboard and was quite stable.

The amount of water ballast to be introduced into the lower compartments to maintain the unit at a convenient level for concreting, was calculated for each lift, bearing in mind that the new concrete must not be allowed to go under water until it was of sufficient strength to resist the external water pressure. As construction proceeded, great care was taken to prevent listing by



Photograph of unit taken a few hours before leaving Tilbury Docks.

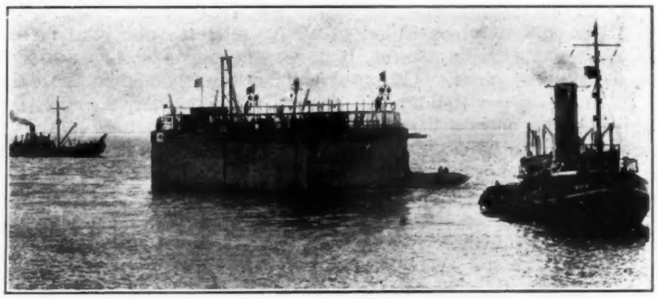
suitable adjustment of ballast, and the draught was carefully checked every day by reading draught markings at each corner.

Ballast concrete in the lower compartments was introduced during the construction at Tilbury and after the unit had been built to a height of 40-ft. 6-in. The amount of ballast concrete required to maintain a metacentric height of not less than 5-ft. was calculated for each lift.

When construction reached the total height of 30-ft. all water ballast was removed and a bracketed scaffold erected around the caisson. Concreting was continued thus until the twenty-second lift was reached, when 600 tons of 15 : 1 lean concrete as ballast was placed in the bottom of the caisson below the lower floor, to ensure that the caisson had its designed draught of 29-ft. when towed to Coryton. At this draught the unit had the necessary stability for the towing operation. This deep draught is greater than that of many large liners.

Shuttering for the concrete walls was made of light timber units, prefabricated in the central joinery works of the contractors, each unit being 2-ft. deep and varying in width from 2-ft. to 6-ft. according to its position in the structure. The predetermined water/cement ratio in the concrete was carefully maintained and an average cube compressive strength of 6,000 lbs. per square inch at 28 days was achieved. The concrete was vibrated by power type immersion equipment. Tubes for grouting under the caisson had been set in position in the structure to fill in any irregularities in the prepared bed at Coryton.

Since the caisson during construction at Tilbury was a floating structure, it was not possible during this period to use instruments for setting out, and reliance was therefore placed on measurement alone from base lines on the structure itself.



Photograph of unit approaching Coryton.

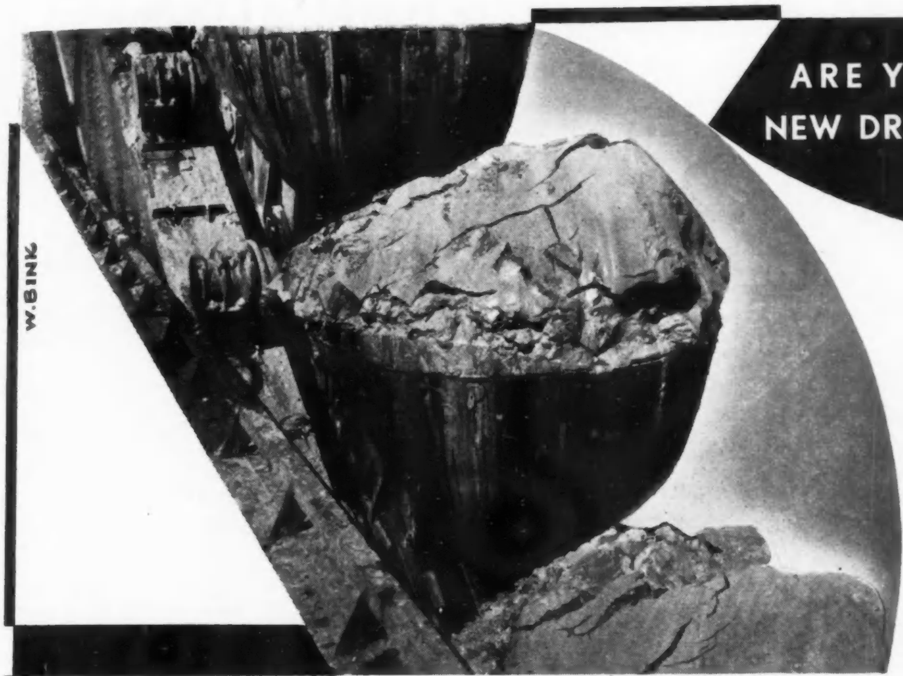
An opening on one side of the caisson was left and temporarily closed by steel sheet piling, which was removed at Coryton to allow space for the steel grids which prevent entry of obstructions to the pump inlets.

Twelve No. 2½-in. diameter "U" type towing bars were cast into the walls of the caisson about 5-ft. above the final water level, and the unit was towed from Tilbury to Coryton by four tugs, one ahead, one astern, one port and one starboard.

A framework of timber piles and timber bracing was provided at the sinking site, and a bolster barge was moored to this framework. A timber template on which the required position of the unit had been marked was fitted on top of the bolster barge, and the unit was manœuvred into position by the tugs, assisted by four winches on the shore, and was sunk within the tolerance specified.

Stone ballast in the lower compartments was introduced at Coryton. The amount required being calculated to ensure that the caisson would not refloat during the completion of the intake construction.

A steel structure on box piles has been provided, designed to carry a number of large pipes, including three of 42-in. and three 39-in. diameter, from the concrete intake to the shore. A reinforced concrete roadway, carried on steelwork and box piles, gives access to the shore from the eastern end of the unit and encloses it on three sides. This structure, together with a structural steelwork and piled extension at the western end, also serves to protect the unit and pipe bridge from damage by drifting craft.



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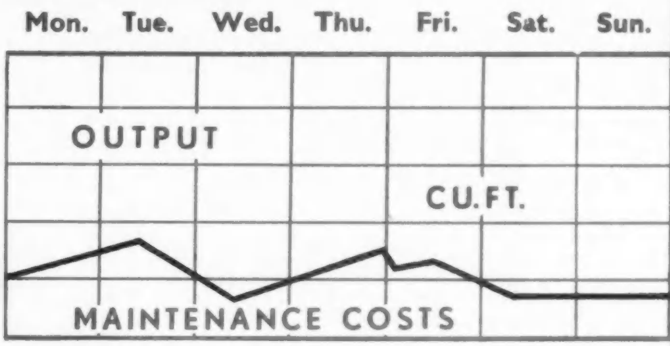

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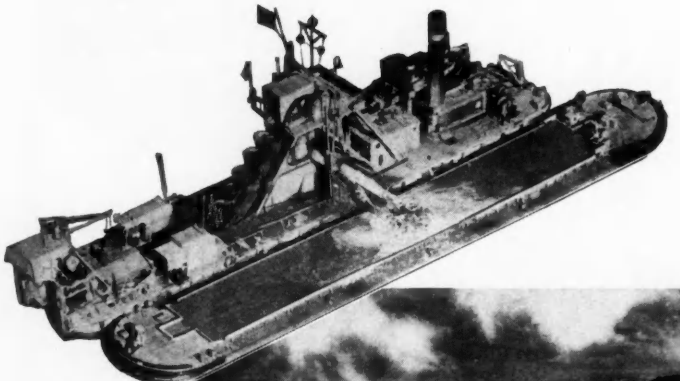

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Elements of Wave Theory

Problems Affecting Coastal Engineering*

By R. L. WIEGEL and J. W. JOHNSON

Respectively, Institute of Engineering Research, and Division of Mechanical Engineering, University of California, Berkeley, California.

Introduction

The first known mathematical solution for finite height, periodic waves of stable form was developed by Gerstner (1802). From equations that were developed, Gerstner (1802) arrived at the conclusion that the surface curve was trochoidal in form. Recent experiments (Wiegel, 1950) have shown that the surface profile, represented by the trochoidal equations (as well as the first few terms of Stokes' theory), closely approximates the actual profiles for waves travelling over a horizontal bottom. However, the theory necessitates molecular rotation of the particles, while the manner in which waves are formed by conservative forces necessitates irrotational motion.

The problem of the maximum steepness (the ratio of the wave height to its length) that a wave could attain without breaking was worked on by Stokes (1847), Michell (1893), and Havelock (1918). Their conclusions were in close agreement. A crest angle of 120 degrees, or a steepness of $H/L=0.142$, was found to be the theoretical limit.

Recently, many field and laboratory studies, as well as analytical studies, have been made. These observations, together with the mathematical studies, lead to the conclusion that Stokes' irrotational theory represents the natural phenomena more closely than the other theories.

Waves in nature vary considerably in height and period over a relatively short length of time at any point of observation. In a generating area, the wave characteristics show the maximum variability; however, even after the waves have passed into a region of relative calm, considerable variations in wave characteristics exist. In theoretical problems, such variability cannot be treated mathematically and certain idealised conditions must be assumed. Accordingly, the first step in the analysis of oscillatory waves is to study the behaviour of single wave trains of uniform period and amplitude as they progress in water of constant depth. Present-day wave theory deals with periodic waves of stable form in which all elements of the wave profile advance with the same velocity relative to the undisturbed water.

Waves of Small Amplitude

If waves are of small amplitude compared to their length and to the depth of the water, the wave profile closely approximates a sine curve. The equation for motion (Lamb, 1932), considering both gravity and surface tension, is :

$$C^2=(gL/2\pi+2\pi\delta/\rho L)\tanh 2\pi d/L \qquad (1)$$

For water deeper than one-half the wave length, $\tanh 2\pi d/L$ is almost equal to 1 and the equation reduces to :

$$C_0^2=gL_0/2\pi+2\pi\,\delta/\rho\,L_0 \qquad (2)$$

where C = wave velocity
δ = surface tension
ρ = density
d = depth of water

Fig. 1 shows the relationships between wave period, wave velocity, and depth of water. Fig. 2 shows the relationships of wave period, wave length and depth of water.

Surface Profile. The surface curve for waves of small amplitude as given by this theory is the sinusoidal equation :

$$y=(H/2)\cos 2\pi(t/L-x/L) \qquad (3)$$

where H = wave height
t = time
x = horizontal co-ordinate
L = wave length

*Excerpts from Paper presented at First Annual Conference of Coastal Engineering held at Long Beach, California, 1950. Reproduced by kind permission.

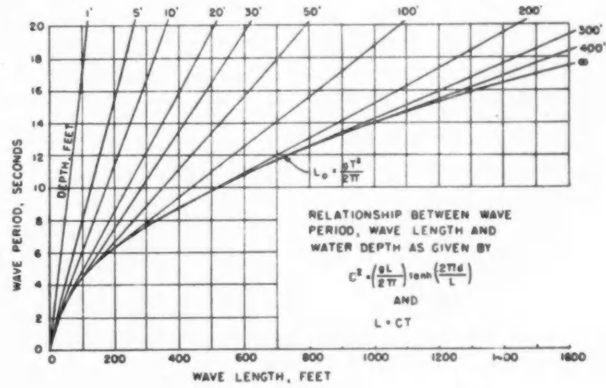


Fig. 1.

Orbital Motion. The motion of the individual particle is elliptical (Fig. 3a).

Energy of Waves. The kinetic energy per unit width (along the crest) for a wave is the summation of the kinetic energy of the particles in motion. For a wave of sinusoidal form in deep water, this is given by,

$$E_k=wL_0H_0^2/16 \qquad (4)$$

The potential energy per unit width for a wave is computed from the elevation or depression of the water from the undisturbed level and is given by,

$$E_p=wL_0H_0^2/16 \qquad (5)$$

It can be seen that half of the energy of a wave is kinetic and half potential. The total energy is expressed by,

$$E=wL_0H_0^2/8 \qquad (6)$$

which, when combined with Equation $L_0=gT^2/2\pi$ gives,

$$E=wgT^2H_0^2/16\pi \qquad (7)$$

where E_k = mean kinetic energy of wave per unit length of crest per wave.
E_p = mean potential energy of wave per unit length of crest per wave.
w = unit weight.
T = wave period.

Sub-Surface Pressures. With the development of the pressure type wave recorder (Folsom, 1949; Isaacs and Wiegel, 1950), it became necessary to utilise the equations for pressure at any point

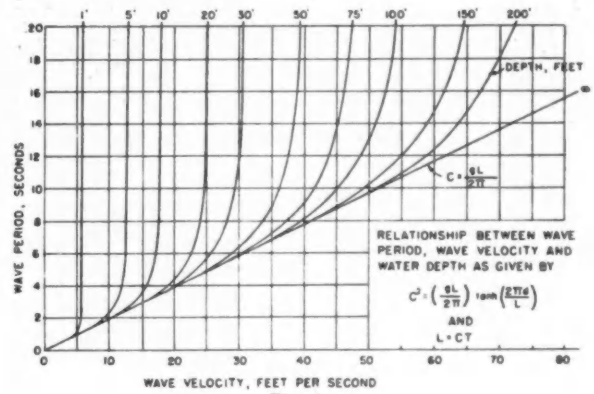


Fig. 2.

Elements of Wave Theory—continued

beneath the water surface. The solution (Lamb, 1932) for an incompressible, nonviscous fluid is,

$$K=[\cosh 2\pi dL(1-z/d)]/\cosh 2\pi d/L \qquad (8)$$

where K, the sub-surface pressure response factor, is the ratio of the pressure at any depth z below the water surface and the pressure at the surface. The ratio of the distance below the surface to the water depth is known as the *proportional depth*. This can be represented in dimensionless form as shown in Fig. 4. Tabulated values have been published by the Beach Erosion Board (Wiegel, 1948). Experiments (Folsom, 1947) show that this approximates the case for waves of finite height. However, for waves of finite height, the measured pressures were about ten per cent. lower than the theory (for very small waves) predicts.

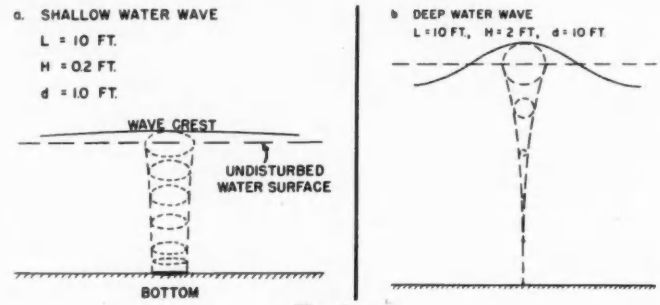


Fig. 3.

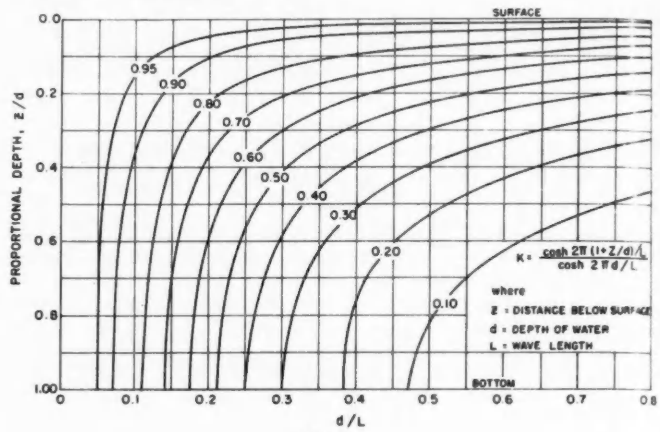


Fig. 4.

Waves of Finite Amplitude

Experiments (Beach Erosion Board, 1941; Morison, 1951; Wiegel, 1950) have shown that the equations for waves of small amplitude continue to be valid, as far as engineering applications are concerned, for waves of appreciable height.

Trochoidal Theory—Infinite Water Depth. The trochoidal theory (Gerstner, 1802), the first theory to be developed for waves of finite height, is often used for engineering calculations. One reason for its use is the ease with which the equations may be used. It appears to represent the actual wave profiles as well as actually satisfying the pressure conditions at the surface and the continuity conditions. However, it requires rotation of the particles and does not predict any mass transport in the direction of wave propagation, while observations (Mitchim, 1940; Beach Erosion Board, 1941) show that there is mass transport. This theory, developed for waves in water of infinite depth, has been well presented by Gaillard (1935).

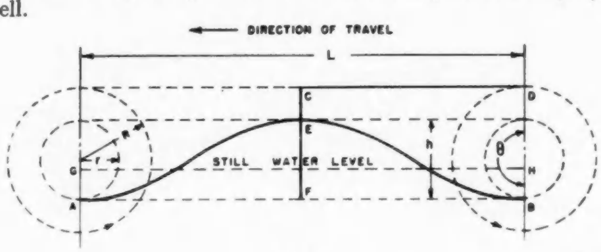
The equations of the surface profile (Fig. 5a) are,

$$x=R\theta-r\sin\theta \qquad (9)$$

$$y=R-r\cos\theta \qquad (10)$$

where R = radius of rolling circle.
θ = angular displacement.
r = radius of tracing circle.

It can be seen that the wave length, L_0, is equal to $2\pi R$, while the wave height, H_0 is equal to $2r_s$, where r_s is the value of r for the surface orbit. Thus, the crest is more than half the wave height above the undisturbed water level, while the trough is less than half the wave height below this level. Experiments performed by the Beach Erosion Board (1941) verify these relationships. It should be noted that they verify the results of the theory of Stokes (1847) as well.



(a) Fig. 5.

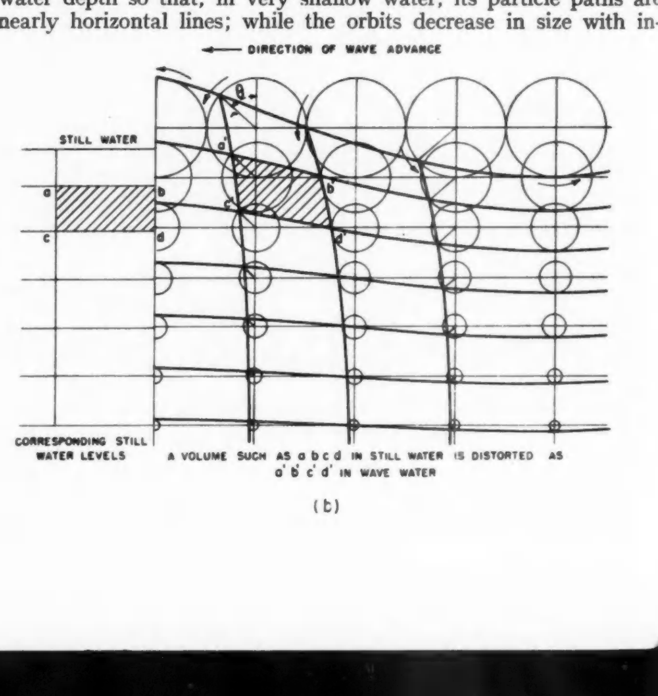
The paths described by the water particles during one cycle are circles with the radii decreasing exponentially with depth (Fig. 5b).

The energy of the wave is equally divided between kinetic and potential, with the total energy being,

$$E=wL_0H_0^2[1-1/2(\pi H_0/L_0)^2]/8$$

Trochoidal Theory—Finite Depth. The trochoidal theory as extended to water of finite depth has been presented by Gaillard (1935) and is widely used. There appears to be no published mathematical work which substantiates the conclusions presented by Gaillard (1935). Perhaps the facts that (a) the wave velocity, orbital velocities and wave shapes as represented in the trochoidal theory were the same as those in the theory of Airy (1845) for waves in deep-water, and (b) other equations of the trochoidal theory reduced to those of Airy (1845) for small amplitudes led Gaillard (1935) to examine the similarities between equations from a reduced (elliptical) trochoidal theory and the Airy (1845) theory for waves in finite depth. The equations of wave velocity, and orbital velocities and shapes as obtained from the reduced trochoidal theory are the same as those of Airy (1845) for shallow-water waves and for small amplitudes. Other reduced trochoidal equations are almost identical to those of Airy (1845). However, the reduced trochoid theory does *not* satisfy either the conditions of continuity or dynamical equilibrium except at the trough and crest (Gaillard, 1935) and hence, this theory, although widely used, is *not* sound.

Gaillard (1935) states that a shallow-water wave differs from a wave in very deep water in that the particle paths are elliptical rather than circular, with the eccentricity of the ellipses depending upon the ratio of the wave length to the depth of water. For a particular length of wave, the eccentricity increases with decreasing water depth so that, in very shallow water, its particle paths are nearly horizontal lines; while the orbits decrease in size with in-



(b)

Elements of Wave Theory—continued

creasing distance below the undisturbed water level with the vertical axes decreasing at a more rapid rate than the horizontal axes until, at the bottom, the vertical motion is zero and the particle moves in a horizontal line. The angular velocity is not constant, but greatest in the vicinity of the trough and crest. It should be noted that this theory predicts that the velocity at the crest of the orbit is the same as the velocity at the bottom of the orbit. Recent experiments performed in the wave channel at the University of California, Berkeley, show that this is *not* true. The actual crest velocities are greater than the trough velocities.

moving forward (i.e., mass transport). This is shown in Fig. 8.

The most interesting result of the theory of Stokes (1847) shows that by not neglecting the effect of height (the velocity of a particle depends not only upon its mean position, but also upon its displacement from its mean position) it is shown that the particle velocity is greater in its forward movement (with the crest) than in its backward movement (with the trough). Laboratory experiments performed at the University of California, Berkeley, confirm this conclusion. This results in the fact that the forward motions of the particles are not altogether compensated by their backward

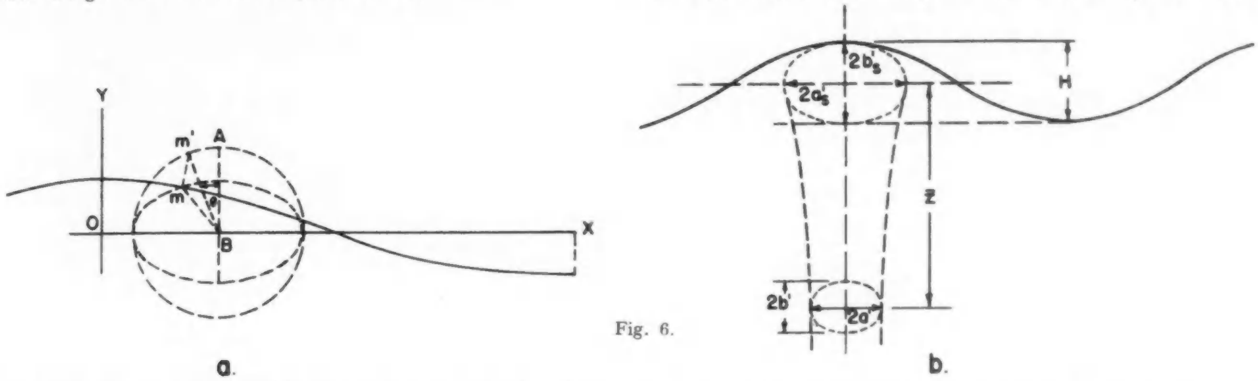


Fig. 6.

The following equations, describing the reduced trochoidal surface, were developed and presented by Gaillard (1935) (Fig. 6),

$$x = R\Theta - a^1 \sin\Theta \tag{11}$$

$$y = b^1 \cos\Theta \tag{12}$$

The velocity of propagation is,

$$C^2 = gLb_s^{\ 1}/2\pi a_s^{\ 1} = gL(\tanh 2\pi d/L)/2\pi \tag{13}$$

The equations for the semi-axes of the orbits are,

$$b^1 = 1/2H[\cosh 2\pi(d+z)/L]/\sinh 2\pi d/L \tag{14}$$

$$a^1 = 1/2H[\sinh 2\pi(d+z)/L]/\sinh 2\pi d/L \tag{15}$$

and the ratio of the semi-axes is,

$$\frac{b^1}{a^1} = \tanh 2\pi(d+z)/L \tag{16}$$

The total energy of the wave, which is one-half kinetic and one-half potential, is

$$E = wLH^2(1 - MH^2/L^2)/8 \tag{17}$$

where M, the energy coefficient, is

$$M = \pi^2/(2 \tanh^2 2\pi d/L) \tag{18}$$

motions. Hence, in addition to their orbital motion, there is a progressive motion in the direction of propagation of the waves. The orbits are open, not closed (Fig. 8). This motion has become known as " mass transport " and is given to the second approximation by

$$U = 1/2(\pi H/L)^2\, C\left[\frac{\cosh 4\pi(d+z)/L}{\sinh^2 2\pi d/L}\right] \tag{19}$$

For deep-water, this becomes,

$$U_0 = (\pi H_0/L_0)^2\, C_0 e^{4\pi z/L} \tag{20}$$

where U = velocity of mass transport.

which is identical with the equation expressing the horizontal velocity remaining (due to rotation) after wave motion has been destroyed in the rotational trochoidal theory. In other words, in order for a wave of finite height to exist, it is necessary for this additional velocity to exist. In the trochoidal theory, it is in the form of molecular rotation (which is *not* substantiated by observations) of particles moving in a *closed orbit*, while, in the irrotational theory, it results from particles moving in an *open orbit* (which *is*

Irrotational Theory. The irrotational theory for waves of finite height in water of uniform depth was developed by Stokes (1847), Rayleigh (1877), Struik (1926), and Levi-Civita (1925). Experimental evidence substantiates the conclusion that this is the theory which most nearly represents actual wave motion.

Stokes (1847) found, to the second approximation, that the velocity of wave propagation is independent of wave height and is the same as the theories of Airy (1845) and Gerstner (1802).

Fig. 7 shows experimental values compared with theoretical values (Morison, 1951). Other experimental work (Beach Erosion Board, 1941) shows approximately the same results. It appears that the experimental error is of the same order of magnitude as the difference between the equations corrected for height and the equations for waves of small amplitude. Because of this, the more simple equation for waves of small amplitude can be used for most engineering calculations.

The particle orbit lies a little above an ellipse at the crest and is a little flatter than an ellipse at the trough while, at the same time, the particle is

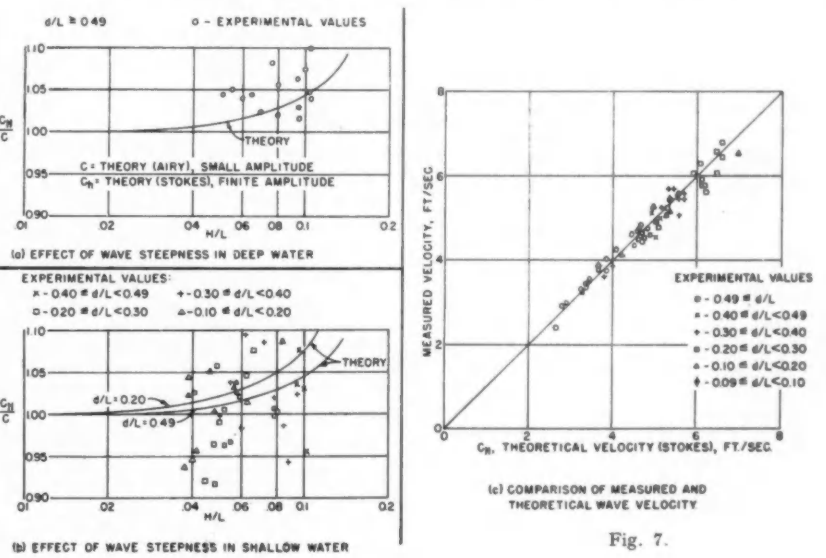


Fig. 7.

Elements of Wave Theory—continued

substantiated by observations (Beach Erosion Board, 1941; Mitchim, 1940; Morison, 1948).

Maximum Theoretical Wave Steepness. Stokes (1847) came to the conclusion that for any wave whose crest angle was greater than 120°, the series would cease to be convergent and hence the wave form would become discontinuous. However, the possibility of a wave existing with a crest angle equal to 120° was not shown until later. Mitchell (1893) found the theoretical limit was $H/L = 0.14$ and Havelock (1918) found it to be 0.1418.

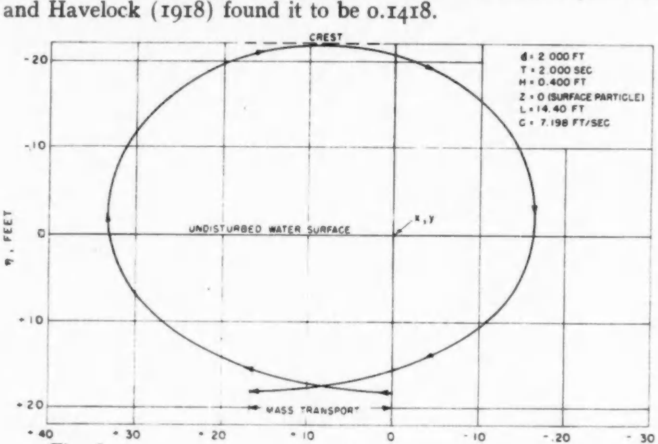


Fig. 8.

Propagation of a Finite Wave Train Through an Undisturbed Media

In nature, an infinitely long series of waves does not exist; rather a train consisting of a finite number of waves, which are formed by winds in a storm area, travels on the ocean surface. These "wave groups" travel at a different velocity than that of the individual waves. Rather simple examples of wave groups are waves generated at the bow of a ship and the waves generated in a wave tank by operating the wave generator for only a few strokes (Beach Erosion Board, 1942). In these cases, it can be seen that the lead wave in the group decreases in height as it progresses, the potential energy being transformed into kinetic energy as the wave form induces corresponding velocities in the previously undisturbed water. The wave finally disappears while, at the same time, a new wave begins to appear at the rear of the group as the velocity pattern left behind is such that the flow converges towards one section and diverges from another section, forming the crest and trough.

The velocity with which the wave group travels (Lamb, 1932) is given by,

$$C_g = 1/2C[1 + (4\pi d/L)/\sinh 4\pi d/L] \quad (21)$$

for waves of very small amplitude in any depth of water. For deepwater, Equation 21 becomes,

$$(C_g)_0 = 1/2C_0 \quad (22)$$

Reynolds (1877), for waves in infinite depth of water, and Rayleigh (1877), for waves in finite depth, developed equations for the transmission of energy by a wave group. In recent literature, the equations have been interpreted to mean that either (a) all the energy advances with group velocity or (b) half the energy advances with the wave-front velocity. However, as Rayleigh (1877) pointed out, for deep-water conditions:

"It appears that the energy propagated across any point, when a train of waves is passing, is only one-half of the energy necessary to supply the waves which pass in the same time, so that if the train of waves be limited, it is impossible that its front can be propagated with the full velocity of the waves . . . because this would imply the acquisition of more energy than can in fact be supplied."

Reynolds (1877) states:

"So that after the waves have advanced through two wave-lengths the distribution of the energy will have advanced one, or the speed of the groups is one-half that of the waves."

From the mathematical arguments of these two investigators, it appears that the energy travels at the group velocity.

Correspondence

To the Editor of *The Dock and Harbour Authority*.

Dear Sir,

Classes for Port Workers

It will be recalled that in 1950 a Conference took place at which the Minister of Education, the Dock and Harbour Authorities' Association, the Institute of Transport and other bodies considered a scheme for an Elementary Course to help Port Workers to a fuller understanding of the Port Industry. The Course was introduced, and its declared aim was to foster the study of the main essentials of Port and Port Working, their problems and background. There were to be three subjects: (a) Port Traffic; (b) Port Working; (c) Port Organisation and Finance.

An Examination was fixed for the end of the One-Year's Course. While not essential, this is regarded as an integral part of the scheme and the Institute of Transport has recognised success in this Examination as a qualification for student membership.

The Evening School of Commerce and Languages, Salford, has included such a Course in its 1951-52 Session, and though it might be rash to draw definite conclusions from a few months' work, some tentative observations may be useful at this stage. Principals of Technical Colleges near smaller ports who are considering provision of the Course may profit from our experience and mistakes, while our observations may contribute towards the projected consideration of the whole scheme by the Institute of Transport.

Detailed preparations for the Course were carefully made and discussed exhaustively between the Port Authority, the Dock Labour Board, the Trade Unions and the Principal and Lecturers of the School. All those concerned co-operated fully in making this Course well known.

The composition of the classes, which had to be triplicated, may be of some interest. Approximately the same number of outside workers and inside workers enrolled for the scheme. Only one of the inside workers, but 40 per cent. of the outside workers, left during the Session. This relatively high amount of wastage during the Session is, however, explained by the difficulties which face most of the outside workers who, because of the nature of their work, which may be extremely dirty, need a lengthy preparation before attending classes, and may perhaps have to work on night work. Despite the slightly better educational background of the inside workers, the outside workers proved at least equal in quickness of understanding, and interest to their clerical and administrative colleagues. They proved to be expert in their particular job, and our conclusion is that it is best to have mixed classes of outside and inside workers because this mixture will contribute to the wider range of experience of the class as such.

The school was very fortunate that the lecturers proved ideal teachers, and found immediately the right and most effective approach to their students. The attitude of the lecturer must be more the attitude of a leader of a discussion group than that of a teacher. His students will in certain aspects have wider experience to their own particular small field than he has. On the other hand he must be able to prevent the discussion from ranging too widely which would make it difficult to cover the syllabus.

The classes at Salford meet on two evenings each week, as this was generally felt to be the maximum time they could be expected to attend. The docks are very busy these days and overtime is well paid, and a third night at school would have meant too big a sacrifice. At the same time it is the opinion of both the Lecturers and the Principal that the subject matter of the three subjects would be better re-arranged into two subjects only, namely:

(a) Port Traffic and Working; (b) Port Organisation and Finance.

It is not suggested that the former subjects (a) and (b) should be simply merged. Certain parts of both these subjects might well be taken out and put into the subject "Port Organisation," e.g., the Historical Growth of the Ports, Dock Labour, Method of Payment, the Dock Labour Board and Industrial Relations. We feel that there would be less overlapping and it would be an advantage to have only one subject an evening. The examination at the end of the session, which is optional, divides the students into two groups, those who are keen enough to aim at it, and those mainly over 40 years of age who, while interested in the course, are not interested in an examination. The latter group, which this year only formed a small minority in Salford, but which in

Correspondence—continued

our opinion will grow, would benefit from a separate class. A short lecture (half-hour) followed by a discussion and a final summing up would be the programme for such an evening. The lecturers could be varied and should be drawn from all parts of the docks.

A very difficult problem on which we have not formed a definite opinion is whether an age limit of 19 years or something similar should be set for entrance to this course. The argument for having such an age limit is that it would be better for younger students to have more general subjects, e.g. commerce with a special regard to Transport, English and Geography. The argument against it is that it would deprive students of the advantage of passing the Port Working Examination before being called up for military service so that after return from the services they could start right away on the Institute of Transport Examination, and our fear that most of the young boys would not come to a class which has a general educational background because there would be a tendency to look at it as a mere continuation of their school activities, and not a professional or semi-professional course.

The next question we asked ourselves was whether this one-year course would form a substitute for a preliminary examination for a professional body. We feel also that the passing of the examination will be a real and sufficient test that the students have reached the necessary standard of maturity to be ready for the full course of the Institute of Transport. It has been suggested (Institute of Transport Bulletin No. 27 for 1951) that English should be introduced into the syllabus. The argument advanced against it, that the inclusion of an academic subject would deter many students, is one with which we agree.

There are no suitable text books available for this particular course. The existing text books, although excellent, are too expensive, and also go too deep. What is needed is a short and precise text book written in easy language. I am sure that amongst the new lecturers who have been taking this course this year are many who have prepared notes, and these notes might perhaps form the foundation for such a text book.

We have no experience yet of the examination but we feel that three evenings of three hours each will be a heavy strain for students who have been working all day and have to take an examination at night. The suggestion made above that two evenings would be sufficient together perhaps with the cutting down of the time from three to two and a half hours would ease the burden materially. At the same time we feel, that a purely written examination may handicap some students, and some thought should be given to the possibility of having a combination of oral and written examination, or even only an oral examination.

A last word about what, although it seems trivial, proved to us of great importance. The responsibility and the full initiative for the running of the course must rest fairly and squarely on the school, and the Institute of Transport. In no circumstances must the impression be given that this course is mainly sponsored by the Dock Labour Board, or the Trade Unions. Suspicion is rife in dockland and grievances die hard. The docker may not trust the Dock Labour Board, and may suspect even his own Union. He will welcome the independent setting of the school, the independence of his lecturers, and he will benefit by mixing with other students of the institute. In our case we preferred to run the course even in our own building which is a grammar school normally used by boys, in preference to better equipped premises offered to us by the Port Authority and Trade Union. We feel that if the impression gained ground that this course is one run by the Dock Labour Board it would not attract the best type of student who wants to keep independent of his employer.

This is the first attempt to bring education to the dock worker. Nothing must stand in the way of making it well known and successful. The efficiency of our docks depends in the last resort on a well informed and alert labour force which understands not only its own job but its background and its place in our economic life. By making this course a success we can contribute towards this aim.

Yours faithfully,
(Signed) R. FOX.
Principal.

Evening School of Commerce,
Salford Education Committee.
April 15, 1952.

To the Editor of *The Dock and Harbour Authority.*

Dear Sir,

Decasualisation at Rotterdam

In your Editorial Comment on the problem of the "Turn-round Delays to Ships in Port" (February, 1952) the remarks you make concerning labour conditions at the Port of Rotterdam are not altogether in accordance with the prevailing position, and I would therefore appreciate it if you would correct any false impression which your readers may have gained.

(1) It is a fact that the dockworkers in the Port of Rotterdam work normally 8½ hours a day and 48 hours a week. Only those stevedoring firms, specialised in the transhipment of bulk goods, i.e. cereals, coal and ores (the so-called mechanical industry) work continuously, and that in a three-shift scheme, not in a two-shift system. The normal working day lasts in this case 7½ hours (40 hours a week). Few dockers are concerned with this trade (actually only about 12 or 15% of the total of dockworkers at Rotterdam) and the cause for this continuous working is to be found in the economic necessity, resulting from the—in comparison with the general cargo transhipment — extraordinary high degree of capital-intensity of these companies.

(2) The Port of Rotterdam has been decasualised since June, 1949, and the following measures are in operation :—

(a) centralisation of the demand for dockworkers;
(b) centralisation of the offer for work;
(c) restriction of the offer, in other words, the forming of one collective reserve for all firms together;
(d) granting of guarantee-wages for the time that the dockers are involuntarily out of work;
(e) the obligation of the dockers to report at a fixed place and time and to accept the work offered to them.

It is perhaps interesting to remark that there is a further resemblance to the English system (and the French) in so far that the dockers do not make any financial contribution.

The differences from the English system are as follows :—

(1) the guarantee-wages are paid for each hour of unemployment (up to a maximum of 48 hours a week);
(2) they amount to 80% of the standard wages per hour;
(3) not taken into consideration are any extra earnings (i.e. overtime, very dirty jobs, etc.).

With regard to these three points of difference, I venture to suggest that in this respect the Rotterdam dockworkers are in a better position than their English colleagues. I also think that this way of payment evokes in the docker a stronger financial stimulus to work, for in the English scheme the extra earnings are taken into account for the calculation of the guarantee "make-up." Not so in Rotterdam.

On July 1st next, it is hoped that a general obligatory "half-pay" and "unemployment"-insurance-scheme will be introduced in the Netherlands (including the Port of Rotterdam), with the consequence that those workers who, in the event of depression of port activity are removed from the register, will receive during a certain period a "half-pay" unemployment-benefit, before they, as unemployed persons, will be dependent on Government's support.

Yours truly,
N. Th. KOOMANS,
General Manager of the Port.

Rotterdam.
8th April, 1952.

To the Editor of *The Dock and Harbour Authority.*

Dear Sir,

English and Dutch Methods of Shore Protection

In his new book "Coast Erosion and Protection" (Chapman and Hall, 1952) the well-known writer of several eminent books on civil-engineering subjects Mr. R. R. Minikin, writes about the Dutch method of Coast Protection as being unnecessarily expensive, even £20,000 to £25,000 per groyne. "The constructions become more and more grandoise and expensive; in fact, viewed against the history of the simple early works of generations ago, it does not appear that these modern methods have even the functional success of their forerunners."

Those "forerunners" were the wooden fence-groynes still used extensively on the English coasts in some form or other. We

Correspondence—continued

abolished these fences about 1730; it would therefore appear that two centuries ago the Dutch engineers protected their coast better, and in a more economical way, than they do now (pages 221 and 222 of the book). Mr Minikin's idea is to promote "sea-sense" and he writes: "It is only right that new works and methods should be tried out, but they must be more closely related to the ends in view." Now this is a rather serious doubting of our horse-sense as well as our sea-sense.

Knowing the English shores fairly well (and admiring their beauty) and having noted down my views on coasts, estuaries and tidal hydraulics in the new "Civil Engineering Reference Book" (Editors Probst and Comrie). I venture to explain the difference between the English and Dutch methods of shore protection as they are to-day. They are as follows:

The Dutch want artificial capes, the English mobile material to protect their coasts. Mr. Minikin says, page 34: "The erosion of high cliffs containing durable minerals is a very useful source of supply of littoral drift for beach economy. The loss of ground surface is surely a small price to pay." Since Holland has no cliffs it has very little littoral drift. There is some, but it is unreliable and halting. The whole coast has a tendency to recede slowly, some parts more than others. We could not pay the small (?) price of loss of ground surface of the receding places and therefore defended those places, of course diminishing the littoral drift by doing so.

The 12 mile stretch between Hook of Holland and Scheveningen with its 66 groynes which are specially evoking Mr. Minikin's scorn, had to be built because the sand dunes there became so narrow that the sea would have broken through. The cape-like expensive groynes have kept the depth-line of 7 metres well out of the shore, and kept the whole low country behind it safe. We have learned to look under water. The tidal currents had to be kept off, well away from the shore. Mr. Minikin says that nobody "should interfere drastically with the natural regimen of the lower foreshore," but we had to do so. There would not have been any cheaper way to escape calamity.

The English method may be the cheapest in England so long as that country can suffer the sea to produce enough littoral drift from its shores. We would perhaps welcome England to provide us also with some material of its eroded shores, but England is on the wrong side of the Channel, and I fear we even would suffer from it in our river and harbour entrances. Littoral drift has its disadvantages too.

Of one thing we are sure; there is no other way to stop sea-erosion than by making or keeping strong capes. In the long run, even in England, the coasts will recede in the same proportion as its capes and cliffs recede, many low parts between the capes and cliffs included.

35, Stalpertstraat,
The Hague, Holland.
April 7, 1952.

Yours faithfully,
DR. J. Van VEEN.

Book Reviews

Maritime Works (Travaux a la mer) by Marcel Blosset. **Published** by Eyrolles, 61, boulevard Saint-Germain, Paris, 5e. 510 figs., 635 pp. price 3950 francs.

This book is divided into four parts: (1) the Elements, (2) Necessary adjuncts to maritime traffic, (3) Construction of Maritime works, (4) Harbour Exploitation. There are 24 chapters, 635 pages, and 500 sketchy illustrations, mostly of the type that would be depicted on a blackboard accompanying a lecture. This is understandable as the author is Professor of civil engineering at the Ecole spéciale des Travaux Publics. It is a feature which is convenient as it rivets attention upon the matters discussed in the text. The book covers a very wide field in one volume, and is a veritable compendium of maritime engineering activities featuring design, construction, use and administration. It will be appreciated that such an extensive range does not allow of detailed treatment, nevertheless, the author has succeeded in producing a volume of great interest upon a technical subject that never becomes uninstructive or boring. Such treatment makes it a valuable aid to students to master the ramifications of the subject before specialising in any of the branches discussed.

The first part deals with wave action, tides, and currents; sea industries, and various schemes for utilising tidal power; hints on constructional materials, etc.

The second part commences with descriptions of post-war vessels and their harbour needs; and then discusses the provisions, from the naval architectural standpoint, for the seaworthiness, security, and navigability, of vessels. The modern development of navigation aids, and recommendations of international conventions, or associations, for safety provisions are examined. Useful notes on the production of charts and the preparation of soundings diagrams are given, lightships, lighthouses, harbour direction lights and radar equipment stations are also treated.

The third part is the most extensive and covers more than half the volume sketching maritime works from harbours of refuge, outer harbours, calling piers, etc., to those works required in the largest of commercial ports. There are 13 chapters in this section dealing with tipped rubble breakwaters and vertical walls and the methods of design and construction; the layout of the essential facilities for discharge and transfer of cargoes to land transport and storage, the expeditious loading, or unloading, and despatch of bulk cargoes, the economics of transporter and luffing cranes, etc. Lengthy treatment is given to the construction of various types of quay walls for shallow and deep water docks and to mooring facilities alongside, wharves, dolphins, buoys, etc. Numerous hints are given on materials of construction and for fendering vessels alongside quays. One of the chapters is devoted to dock gates and shipping locks. Then follows a chapter on grids, shipbuilding and repair berths, slipways, and floating docks. Various types of bridges for spanning navigable waterways and channels are described. Other matters receiving attention are: dock and harbour maintenance, wreck removal, dredging, etc. Then follow chapters on coast defence and the improvement of tidal rivers, and canals.

The fourth part, of three chapters, deals with commercial, administrative, and special matters such as seaplane bases, oil ports, fish marketing facilities, and the duties of a harbour engineer.

To sum up, the book is most interesting reading and gives full attention to the essentials of the subject as a whole. It provides an excellent, although sometimes a sketchy, summary of the construction of maritime works and maintenance, and should be of great use to young engineers wishful to acquire information over the whole of maritime harbour activities. R. R. M.

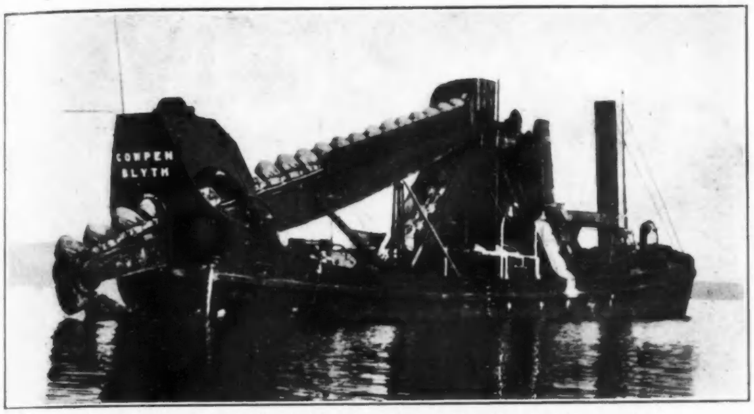
Three Hundred Years on London River by Aytoun Ellis, The Bodley Head, 30s.

This book is the Hay's Wharf story from 1651 to the present day and is rich in the history of riverside Bermondsey and Southwark. It traces its development from a small wharf to the present-day continuous line of wharves extending from Tower Bridge to Bankside with ancillary cold stores and wine and spirit vaults lying behind the riverside warehouses. The book also traces the development of the lighterage, cartage, and shipping and forwarding interests associated with the present-day company, The Proprietors of Hay's Wharf, Ltd.

In the early days of Hay's Wharf hoys and other sailing coasters were the only vessels to berth at the wharf. In the early part of the nineteenth century there were services from the wharf to Swansea, Plymouth, Stockton, Ipswich and other coastal ports. In the middle of the century the China clippers came to the wharf to be followed later in the century by steamers. The author has dealt generously with the history and the warehousing side of the Hay's Wharf business; he has also brought into his narrative the family records of those far-seeing men who built up the business as London knows it to-day, but much of interest has been lost by not telling the reader something about the ships which so many thousands of Londoner's see day by day as they cross London Bridge.

The book is well illustrated with old sailing bills, maps, plans and contemporary pictures and prints. Several of the illustrations have been specially painted by the author's son, Mr. Gordon Ellis. A. G. T.

DREDGERS AND DREDGING PLANT



Twin Screw Stern-Well Bucket Hopper Dredger, "Cowpen."

Bucket Dredgers
Suction Dredgers
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Hydraulic Agitators
Floating Pipe Lines
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Sewage Vessels
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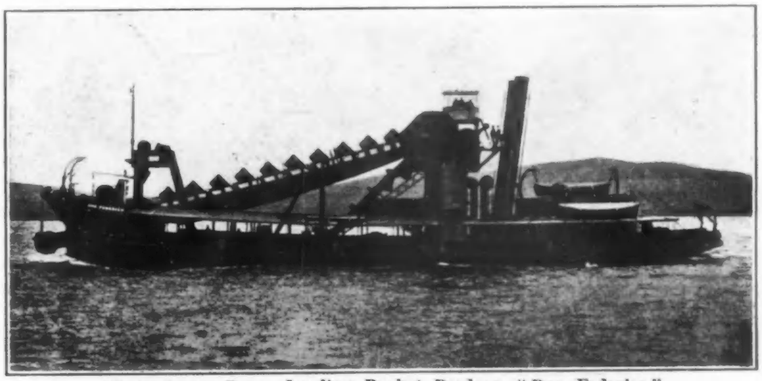
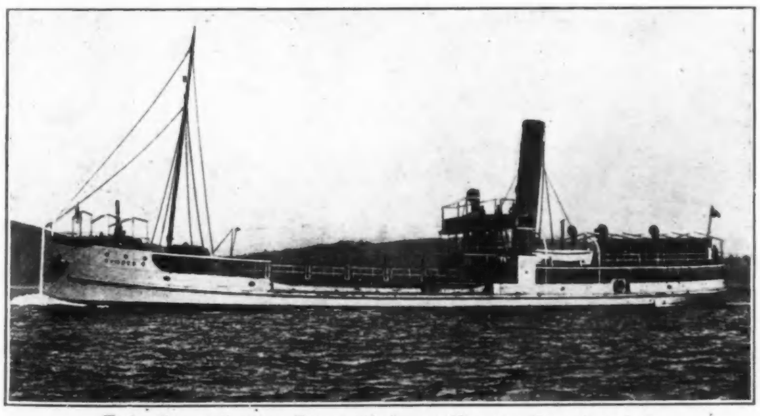


Twin Screw Barge Loading Bucket Dredger, "Don Federico."



Twin Screw Suction Pump Discharge Hoppers Nos. 4 and 5.

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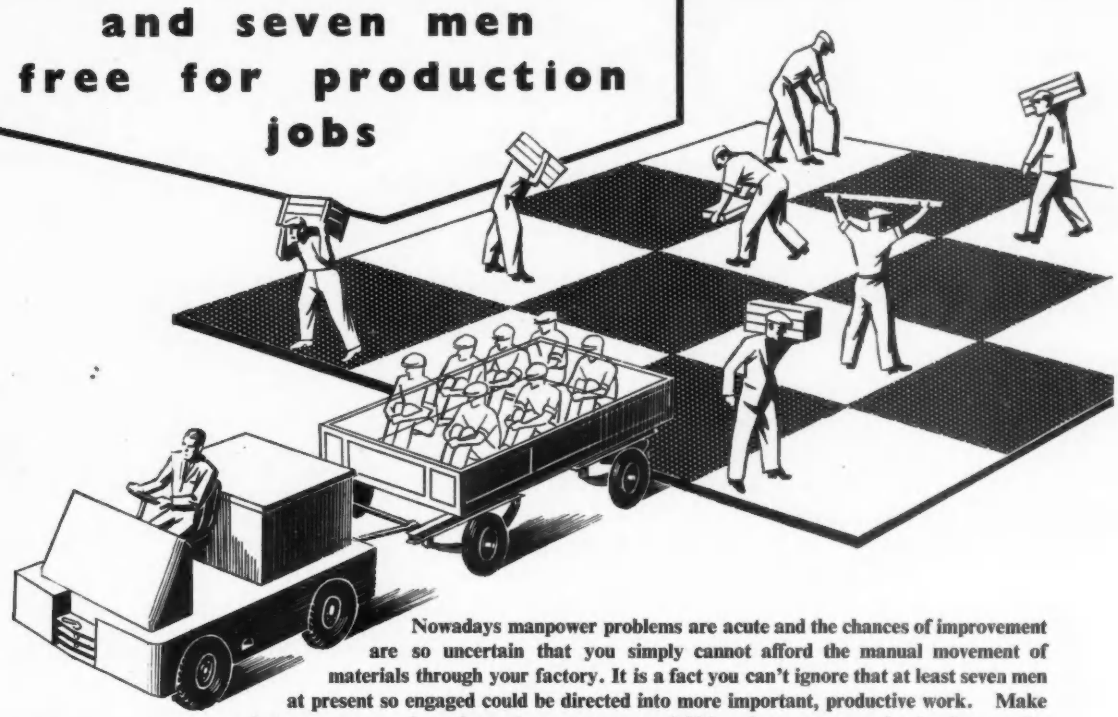

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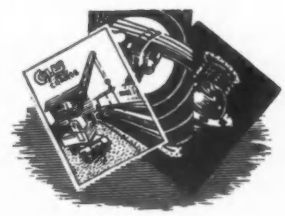

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Tch/2/4

Reconditioning an Old Jetty

Interesting Comparison of Three Types of Construction

(Specially Contributed)

IT SELDOM HAPPENS that an opportunity arises to compare the performance of three different types of construction which have been exposed to exactly the same service conditions. Such an opportunity has, however, recently arisen in connection with certain repair work that the Consulting Engineers, Messrs. Maunsell, Posford and Pavry were called upon to carry out upon the Queenborough Coaling Jetty, owned by Messrs. Settle Speakman and Co. Ltd., which is situated in the tidal creek which separates the Isle of Sheppey from the mainland close to the point where the River Medway debauches into the Thames Estuary.

The form of construction adopted in the latest repair work employs bare steel as the structural element. The older part of the jetty was built partly in timber and partly in reinforced concrete. A triple comparison is therefore afforded.

The original jetty built in 1907, is a typical example of an early effort at wharf construction in reinforced concrete. It consisted of a curved approachway carrying a double track railway. The approachway was supported on piles and led up to the unloading jetty which was also a piled structure. The latter was 185-ft. long and upon it were mounted 3-ton grabbing portal cranes running on outer tracks. There was a coal conveyor mounted on the inboard side. Ships were berthed in front of the wharf where there is a depth of 33-ft. of water at high water of spring tides, the tidal range being 19-ft. at springs.

Barges were berthed at the back of the main wharf where the depth of water was much less.

A timber extension 120-ft. long, shown in Fig. 1, was built in the year 1920, and then in 1933 when both the reinforced concrete section were becoming unsafe, a reinforced underpinning scheme was undertaken by Messrs. Peter Lind and Co. to their own design. This underpinning scheme involved the driving of 80 reinforced concrete piles, each of which was over 60-ft. in length and which carried heavy reinforced concrete capping bents.

The old deck structure was eventually supported off these new capping bents.

Further repairs to the underside of the old decking were found to be necessary in 1938 and the restoration of these defective beams and slabs was only half completed when the war intervened and prevented the completion of the work.

It is instructive to consider the nature and the causes of the deterioration, both of the early reinforced concrete structure and of its timber extension.

It must be remembered that the reinforced concrete designer of those days, 40 or 50 years ago, had himself frequently to face the

Fig. 1.

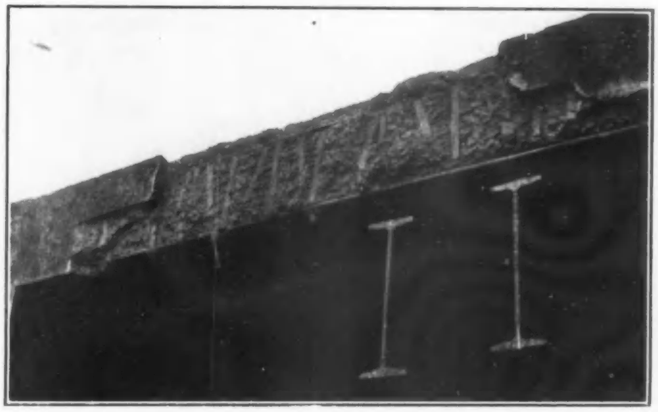


Fig. 2.

competition of other designers claiming to be specialists in the field of reinforced concrete design. Under such conditions, the designers themselves were compelled to attempt the utmost economy in design which very often involved sacrificing solidity and durability. In addition to the competition which existed among the different specialist designers, it almost always happened that the execution of the work came to be awarded by competitive tender and the contractors of those days had, in order to get work, to cut their prices to a greater extent than is nowadays usual.

The early reinforced concrete designs were simulacra of the time honoured timber constructions that they were designed to replace; that is to say, they were braced lattice structures. There were two levels of longitudinal and transverse members, the upper layer situated just above high water and the lower layer situated a short distance above low water. Between these two horizontal layers of bracing members were a number of inclined or raking members some of which were disposed lengthways and others transversely.

The designers rarely made use of one of the main advantages of the new material which was the integration of the whole structure by means of a continuously reinforced deck slab and the elimination of bracings by means of raking piles.

It is probable that much of the cracking of the concrete connections which took place in this old jetty was originally brought about by the subsidence of the outer side of the jetty and the consequent tilting of the whole structure. The tilting in question, which undoubtedly took place, appears to have been the result of insufficient bearing strength on the part of the piles on the deep water side of the jetty. Although this subsidence and tilting of the jetty was probably responsible for most of the fractures it is quite likely that some of it was also due to the defective character of the original design in which a fully braced rigid upper part is imposed upon an unbraced lower part consisting of vertical pile shanks below low water. It is particularly noticeable that wherever cracks have occurred, the reinforcing bars have become exposed to attack by rust and the effect of this has been to set up internal pressure causing more of the concrete to spall off so exposing more of the bars to rusting. This process which has been active in parts of this structure for over 40 years has in places resulted in causing almost complete corrosion of the reinforcement.

There are, on the other hand, parts of the original reinforced concrete structure which were not exposed to cracking and where practically no deterioration has occurred in all these years. The weakening of a member, as illustrated in Fig. 3, by the heavy loss of concrete compression area is usually a more serious factor than the loss of tensile steel area due to direct rusting.

Reconditioning an Old Jetty—continued

Fig. 3.

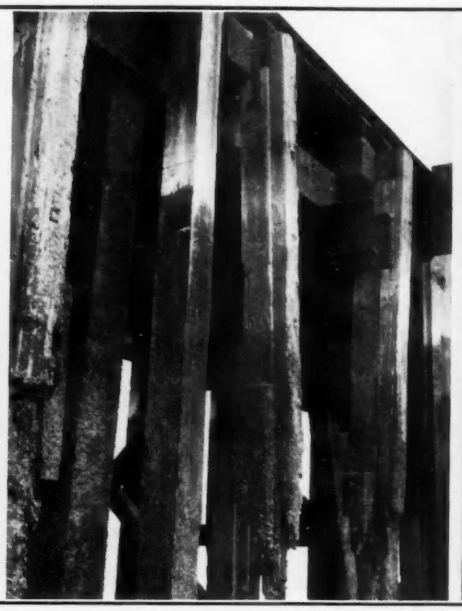
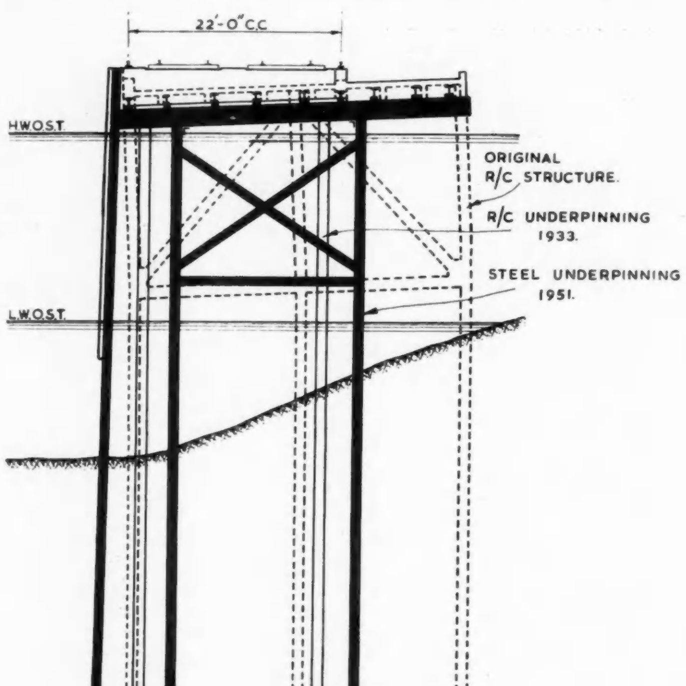


Fig. 4.

Fig. 5.

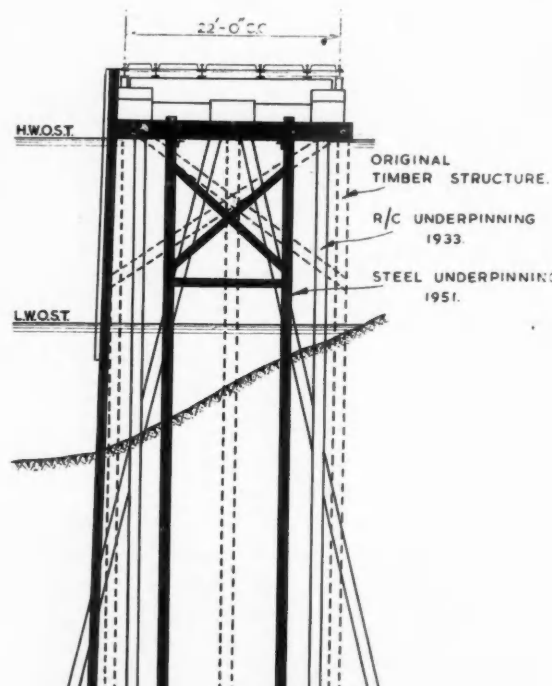
Another special cause for deterioration was the use of flat iron stirrups in part of the early construction. The collection of rust on these flat iron stirrups has produced the excessive amount of spalling shown in Fig. 2. It is interesting to note that in other places where the main reinforcement bars were hooped by means of round stirrups, the spalling was much less extensive.

Another thing which has to be remembered is the extraordinarily unfavourable conditions under which many of these old reinforced concrete wharves had to be constructed. It was quite usual in those days for the fixing of the shutters, the steel reinforcement and also the deposition of the concrete to be made to take place between tides in exposed position and often by night. In those days also, even after a jetty of this kind had been built it was likely to be regarded by the shipmasters and watermen as a fair target for a trial of strength with their craft and was subjected to a good deal of hard usage.



SECTION OF CONCRETE PORTION OF JETTY.

Fig. 6a.



SECTION OF TIMBER PORTION OF JETTY.

Fig. 6b.

Reconditioning an Old Jetty—continued

Taking all these considerations into account, it is very remarkable that any of these old structures should have lasted as well as they have done.

It has been mentioned above that the timber extension to the reinforced concrete jetty had also been found to have deteriorated very much after only 30 years' service. The deterioration in this case was to a large extent caused by marine borers below higher water and by improper disposition of the timber above high water. The timber work above high water was frequently allowed to be in contact with deck filling material. Being unable to dry out, this timber soon became rotten. An example of rotting produced by the Limnoria marine borer near a low water level is shown on Fig. 4. In these cases the upper part of the piles were still sound and the lower parts embedded in the mud were also unaffected.

This particular structure seems to have been built in Douglas Fir obtained from British Columbia or Oregon, U.S.A. and the timber does not appear to have been creosoted under pressure before its employment. The ideal timber to use for such work would have been Greenheart because of the much greater immunity which Greenheart possesses against attack by marine borers. Pitch pine timber would also have been much more durable. In those days, this easily worked, extremely strong material was readily obtainable for a moderate price but after the 1914-18 war,

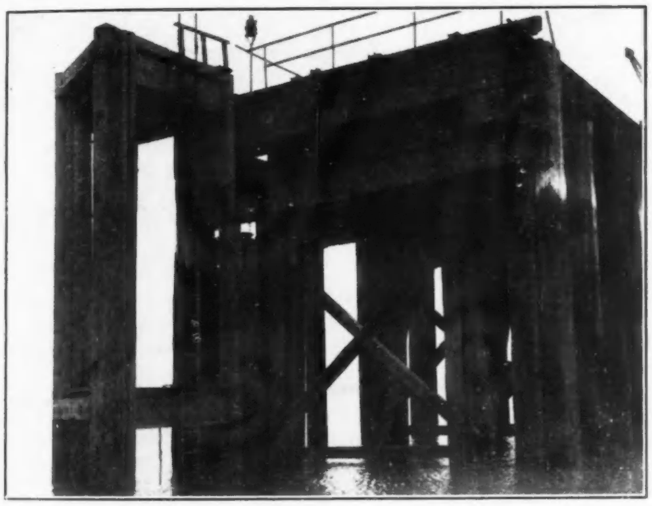


Fig. 7.

both Pitch Pine and Greenheart became more difficult to obtain and this led to the use of inferior Oregon timber.

A comparison of the structural forms is shown in Fig. 6 in which (a) is a cross section of the original reinforced concrete jetty, shown dotted, and (b) is a similar view of the 1920 timber extension, also shown dotted. The reinforced concrete restoration work carried out in 1933 is shown on both in full line, and shows the use of raking piles underpinning the timber extension. This eliminated the possibility of any bending moments being set up in the piles due to horizontal forces, and avoided racking stresses at bracing connections.

The most recent improvement which has been carried out is also shown in Fig. 6a and b (in solid black).

The latest restoration design by the consulting engineers, took into account the owner's intention to replace the original 3-ton by 5-ton level luffing Stothert and Pitt 22-ft. gauge portal wharf cranes. It was clear that the existing deck beams could not take any of the additional load, so the scheme adopted was to halve the span of the beams by placing another piled bent between each of the original transverse bents. The new cross beams were composed of twin 24-in. by 7½-in. R.S.J's. connected to 12-in. by 12-in. broad flange beams driven as piles as shown in Fig. 5 the joint being concreted to prevent rusting.

The owners required that there should be no hold up in the berthing and unloading of ships due to the reconstruction, nor should the loading of barges, wagons, trucks and conveyor be affected. The method of pile driving adopted to achieve this was to pitch the piles in lengths of 35-ft. using the wharf cranes, when these were not required for unloading. The piles were pitched through holes cut in the deck, and were driven without leaders by a No. 7 McKiernan Terry hammer.

The first pile was driven to a set of 150 blows to one foot, and was tested by running a locomotive on to the track above and jacking against the underside of the rail bearers. There was no subsidence under this load of 44 tons.

The 12-in. x 12-in. broad flange beams were also driven as fender piles on the front of the jetty and in contact with it at deck level. Elm fenders were fitted into the beams on the outside face and the long unsupported length gives the necessary spring to the fender when bumped by river craft. Small bollards of the "Bean" type were fixed to the top of the fender piles as there was no room to fix them between the crane tracks and the edge of the wharf.

The whole structure was braced by 8-in. x 8-in. angles as shown in Fig. 7. All the exposed surfaces of the new work were heavily coated with bitumastic paint, as also were most of the old concrete surfaces.

The independent dolphin shown in Fig. 7 is capable of taking the force of end collision due to rough berthing, and consists of Larssen No. 3 box piles.

The performance of this restoration in steel will be closely followed. It is expected, however, that bitumen coating will defer the corrosion of the one inch thickness of metal in the piles for a very long time.

The contractors who carried out the latest steel underpinning scheme with great economy and despatch were Marples, Ridgway and Partners Ltd.

Civil Engineering Code of Practice No. 2
Earth Retaining Structures

This Code is one of a series which is being prepared and published under arrangements made by the Civil Engineering Codes of Practice Joint Committee constituted by the Institution of Civil Engineers, the Institution of Municipal Engineers, the Institution of Water Engineers and the Institution of Structural Engineers. It was prepared by a Committee convened by the Institution of Structural Engineers. A draft of the Code was submitted for comment to certain leading authorities on the subject, to professional and industrial organisations and to others intimately concerned with the matters covered by the Code at home and abroad.

This Code deals with the design, construction and maintenance of all types of structures required to retain soils at a slope steeper than that which they would naturally assume, or to protect soil banks against destructive agencies. It is applicable to structures for retaining solids other than soils provided their relevant characteristics can be ascertained but it does not deal with structures for retaining liquids.

Matters which affect all types of earth retaining structures are first discussed. These include the estimation of the forces in the surrounding soil which threaten or promote their stability, the various types of structure and the reasons for their choice, and such details of design, construction and maintenance as are applicable to all types. Subsequently the various types of structure are dealt with in turn and recommendations regarding the materials to be used and special points affecting the design and construction of each type are given.

Additional information is given in a series of appendices, items of special interest being an account of a number of wall failures which have occurred and a description in some detail of various methods of underwater revetment. A bibliography is included.

Copies of the Code are obtainable from the the Institution of Structural Engineers, 11, Upper Belgrave Street, S.W.1, price 15s. post free.

Port Economics

Part 5. Port Finance

By A. H. J. Bown, O.B.E., F.C.I.S., M.Inst.T.
General Manager and Clerk, River Wear Commissioners, and General Manager, Sunderland Corporation Quay.

IN an earlier chapter it was suggested that the science of economics is largely expressible as a matter of money. The financial affairs ot port authorities, just as those of other organisations, reflect the push-and-pull of economic forces and, in the paragraphs now following, an attempt is made to analyse this process and to suggest some of the basic principles which influence its operation.

Capital structure and assets.

The economist recognises three factors of production—namely labour, land and capital, but when he comes to define capital for us he does not always agree with his fellow-experts. However, we may accept from Alec Cairncross (Introduction to Economics) the plain statement that capital means property, money and securities. Examples of all three are to found under the general heading of assets on the righthand side of the balance sheets of port authorities. The following is a composite list drawn from several such sources :—

(1) **Capital Expenditure**—that is, expenditure to date on land, buildings, plant, etcetra, less Government grants and other credits received, and less amounts written off out of revenue. The schedule of capital expenditure may contain the following detailed heads :—

- Original cost of dock works
- Original cost of river works
- Miscellaneous dock and river works
- North Harbour and Jackson Dock works
- Lock Works, North Outlet
- Extension and improvement of Pearson Dock
- Improvement of West Dock
- Graving Docks
- Coal drops, railways and approaches
- Warehouses, Sheds and working plant
- Protecting piers
  - Lucas Pier
  - New West Pier and contingent works
  - Strengthening South West Pier
- Dredgers and other floating property
- Harbour entrance improvement works
- Harbour improvement works
- River improvement works
- Head office building and furnishings
- New workshops
- Reclamation of 20 acres at Southdene
- Widening and deepening No. 2 Junction Gateway
- Improvement of West Side, Jackson Dock
- Echo sounding equipment
- Removal of Strand End for river widening
- Widening of river near Palmerston Bridge
- Rock dredging in Outer Basin

(2) Sinking Funds—Cash at bank on deposit account.
(3) Stock of stores and materials on hand.
(4) Sundry debtors.
(5) Charges paid in advance.
(6) Cash at bankers on current account.
(7) Cash at bankers on deposit account.
(8) Cash in Treasurer's hands.
(9) Investments in Defence Bonds etc.

As will be seen, the above-given list includes the tools of the port authority's trade, the special sort of premiess it must possess in order to do its work, some ready money, other money earned and put aside for special purposes, and yet other earned money saved and invested outside the undertaking and available if required. Such is the typical make-up of a port authority's capital.

On the other side of the balance sheet is the story of how these possessions have been acquired, how far they have as yet been paid for, and some indication of the financial strength of the undertaking. A composite list of representative items is given below :—

Capital Loan Debt.

Funded debt.

- $4\frac{1}{2}$ per cent. annuities.
- 3 per cent. annuities.
- $3\frac{1}{2}$ per cent. Second Mortgages.

Bonds and mortgages.

- First mortgages.
- Second mortgages.

Piers Loan.

Capital Loan Redemption Account.

- Sinking Fund "A."
- Sinking Fund " B."
- Other amounts transferred from revenue and applied in repayment of loans.

Capital Reserves.

Reconstruction and renewal of works.

Amounts set aside out of revenue less total expended to date.

At the risk of stating the obvious, a few sentences of explanation are here inserted for the benefit of such younger students as may not be completely familiar with the balance sheets of port undertakings.

The capital loan debt.

This is money borrowed from and still owing to the public upon the security of the revenue of the port undertaking. It has all been devoted to the creation or purchase of revenue-earning assets. In the example given above, the differing rates of interest largely reflect the differing conditions of the money market at the time of borrowing: the rate is also liable to be affected by the term—that is, the period of years for which the money is lent and at the end of which it must be repaid unless the loan is renewed by agreement on the same or revised conditions. In the United Kingdom, it has been a Treasury regulation for some years past that such loans must be for the period of seven years at least. Formerly much money was lent and borrowed for shorter periods, such as three years, and was often thereafter left remaining on loan with a six months' notice condition on either side. If lenders do not wish to renew at the expiration of the term, the port authority must find other lenders to take their place, unless there are reserves available out of which it is decided to use money to extinguish the debt.

Division of the capital loan debt.

In the composite example given earlier, the capital loan debt is shown in three parts—(1) funded debt; (2) bonds and mortgages and (3) piers loan. In illustration of some of the different forms which port authority loan debt may take, it may be useful to explain that the funded debt, in the example, was created, section by section, by offering funding terms to a large number of separate mortgage holders. These operations were carried out by the port authority at different times through a firm of merchant

Port Economics—*continued*

bankers when interest rates were reasonably settled, the bankers underwriting the several transactions. The advantage to the port authority was increased stability and simplification in its capital structure because a large number of separate short term mortgages, liable to fall due at different dates, were converted into one large debt for a much longer term at a known rate of interest. In the example quoted, by far the greatest part of the funded debt is that upon which the rate of $3\frac{1}{2}$ per cent. is being paid. It was created in 1935 and must be repaid during the ten-year period 1955 to 1965, the port authority choosing its own time during the course of that ten years The funded debt is dealt in on the Stock Exchange and the port authority registers transfers and transmissions on the payment of a small fee.

The bonds and mortgages represent sums of money borrowed from individual persons, firms or societies. The first mortgage capital is the oldest and highest ranking security of the Undertaking. In subsequent private Acts, the name of first mortgages was reserved to this particular borrowing and its total sum was fixed—hence the application of the term second mortgages to later borrowings. There are many lenders and the periods and rates of interest vary according to the state of the money market when the money was borrowed. The common procedure is to obtain such loans when they are required through firms of investment brokers to whom a procuration fee is paid. As used here, there is no effective distinction between the two terms bonds and mortgages.

The piers loan is separately stated because it was raised under a special statutory power for the construction of new outer piers and is in a slightly different form. The authority was authorised to charge a new and additional tonnage due in respect of the piers and upon this revenue the piers loan is particularly secured. It It was borrowed wholly from one source and was made repayable over a period of sixty years, interest and capital repayment being taken care of by regular annual combined payments.

Redemption Account.

The total sum given in this section shows the extent of the port authority's success in paying back money borrowed for the purpose of purchasing, extending and improving the undertaking. In the headings given in the foregoing example, it will be seen that there are two sinking funds and a general item: in this case, the two sinking funds are maintained in accordance with specific statutory requirements and relate, respectively, to two particular parts of the authority's loan debt. The general item is made up of sums charged against revenue in various past years and used to pay off other parts of the loan debt.

A large redemption account and a comparatively small capital loan debt indicate financial strength. They do not, however, necessarily guarantee that the over-all condition of the authority's undertaking is healthy and vigorous. For example, if capital debt has been redeemed so fast that maintenance has had to suffer, then the consequent poor state of the physical assets may outweigh the satisfactory appearance of the balance sheet. Again, if a spirit of timidity has stopped desirable expenditure upon extensions to the port facilities, then, even if the old facilities have been thoroughly maintained, it may well be that on paper the undertaking is prosperous but, in actual fact, has been allowed to lapse into an obsolescing state. There are no set rules for the guidance of port administrators in such matters as these: knowledge of the right course to pursue is only born of the wisdom obtained from long experience—and especially from experience of a particular port, its history, its peculiarities, its special task in the national economy, and its future prospects.

Capital and Revenue reserves.

As with all balance sheet reserves, the reserves of a port authority may be represented by corresponding investments outside the undertaking itself, or they may be included in the value of the authority's own facilities. In any particular case the position may be ascertained by an examination of the assets side of the balance sheet. Capital reserves may be created by the sale of assets in excess of original cost, or again, by issuing bonds or stock at a premium. Revenue reserves may have been derived from accumulated surplus revenue realised in past year and left as a favourable balance without specific appropriation; or revenue may have been charged from time to time and reserve accounts with varying titles thus created—such as general reserve, port improvement reserve, renewals reserve, and the like. When a desirable time comes for the utilization of such reserves, or part of them, if there are corresponding outside investments then such investments may be turned into cash to meet the particular contemplated expenditure. On the other hand, reserve accounts which have no corresponding investments outside the business, but are represented in the increased value of the undertaking on the assets side, remain on the liability side and are of benefit to the undertaking in that the loan debt has been kept down by a sum corresponding to the reserve. Furthermore, in any year of abnormally high revenue expenditure, a renewals reserve account could be used to keep down the charges against revenue in that year.

Port revenue and expenditure.

Turning to annual income and expenditure, the following main heads relate to a United Kingdom port undertaking owned and operated by a statutory public trust and consisting of docks as well as a harbour and length of river :—

Income. Dock tonnage dues on vessels, coal shipment charges, wharfage receipts including dock dues on goods, warehouse receipts, graving dock receipts, rents of sites, port dues on vessels (made up of tonnage dues, refuge dues, mooring dues, lighthouse dues, river loading dues and launching dues), port dues on coal, port dues on goods and miscellaneous receipts.

Expenditure. (1) **Operating expenses.** Wages paid to officials and staff docking and undocking vessels, to graving dock staff, to officials and staff concerned with coal shipping, dock railway working, and supervision and operation of cranes, wharves and warehouses; payments to sub-contracting master stevedores loading and discharging vessels; wages of dock watchmen; salaries and wages of officials and staff of harbourmaster's department; wages of staff operating lighthouses and signals; charges for electricity, gas, coal and fresh water; and municipal rates payable in respect of port and dock estate.

(2) **Maintenance and renewals.** Repairs and replacements to dock gates, bridges, graving docks, quays, piers, sea defences, moorings and buoys, coal staiths and approaches, wharves, warehouses, cranes, cargo handling appliances, locomotives, dock railways and roads; wages to staff surveying, sounding and removing obstructions ; maintenance of lighthouses, signals, shore radar installation and engineers' workshops; and maintenance dredging of harbour entrance channel, river and docks including upkeep of dredging craft.

(3) **Administrative expenses.** General salaries and wages ; insurances — accident, national, fire, boiler, craft, third party ; printing, stationery and advertising ; postages and telephones ; superannuation allowances and contributions; and legal and parliamentary expenses.

(4) **Financial charges.** Interest on loans, mortgages and funded debt ; stamp duties and loan charges ; contributions to sinking funds for debt redemption; and income tax.

In later chapters in the present series, further detailed reference will be made to some of the aforementioned classes of revenue and expenditure. For the moment, the table on the following page will be of interest to the student. The figures given relate to the finances of 24 port authorities—18 in the United Kingdom and 6 in other countries. They may serve to show something of the general trend of relationship as, for example, between invested capital and gross and net revenue, and again, between annual revenue and expenditure. Another point of interest is how the present capital value of the undertaking has been built up—as between money borrowed, on the one hand, and, on the other, money earned by the undertaking itself in past years. The proportion between total borrowings and debt redeemed is also worth noting.

Port Economics—continued

No.	Type of Undertaking	Capital Expenditure: Out of revenue, or reserves, or other sources other than borrowing	Capital Expenditure: Out of borrowings	Capital Expenditure: Total	Total of borrowed capital Redeemed	Total of borrowed capital outstanding in a recent year	Gross revenue in a recent year	Expenditure against revenue in a recent year	Result: Surplus	Result: Deficiency	Remarks
		£ Thousands	£ Thousands	£ Thousands	£ Thousands	£ Thousands	£ Thousands	£ Thousands	£ Thousands	£ Thousands	
1	A public trust	4,438	46,034	50,472	8,275	37,759	6,727	6,611	116		
2	do.	969	43,793	44,762	11,082	32,711	11,089	10,167	922		
3	do.	2,777	6,085	8,862	3,481	2,604	1,400	1,379	21		
4	do.	1,926	2,773	4,669	1,165	1,608	366	373		7	
5	do.	1,624	2,476	4,100	934	1,542	589	583	6		
6	do.	95	3.577	3,672	653	2,924	375	352	23		
7	do.	858	2,158	3,016	1,038	1,120	330	194	136		
8	do.	35	2,694	2,729	1,865	829	253	211	42		
9	do.	845	1,314	2,159	906	408	188	193		5	
10	do.	457	1,000	1,457	193	807	264	236	28		
11	do.	472	587	1,059	58	529	162	147	15		
12	A company	816	129	945		129	182	150	32		
13	A public trust			898			138	121	17		
14	A company	90	400	490		400	163	109	54		
15	A public trust	133	296	429	200	96	44	47	3		
16	Municipal	10	52	62	30	22	5	9		4	
17	A public trust		123		82	41	73	71	2		
18	British Transport Commission, **Docks, Harbours and Wharves**										
	Scottish						589	684		95	Before charging interest on capital or redemption contributions
	North Western						1,358	1,624		266	
	North Eastern						1,053	720	333		
	Humber						2,862	3,164		302	
	South Wales						3,025	3,230		205	
	South and South Western						2,644	2,106	538		
	Others						967	1,025		58	
	Totals :—Net book value of fixed assets as last adjusted and published :— **£68,503,916** less a proportion of the Assets Displacement Account						12,498	12,553	871	926 871 55	
19	An Indian port Rupees	1,92,89,054	24,34,46,253	26,27,35,307	8,76,07,250	15,58,39,003	5,92,28,591	5,87,52,007	4,76,584		
20	A U.S.A. port Dollars		13,800,000	13,800,000	865,000	13,070,000	703,537	643,908	59,629		
21	A Tasmanian port £	244,482	327,430	(Since 1912 571,912	246,000	81,430	83,927	73,680	10,247		
22	An Indian port Rupees	2,38,20,393	3,15,20,414	5,53,40,807	2,56,65,975	58,54,439	1,18,66,526	1,08,70,720	9,95,806		
23	A West African port £	479,197	3,104,416	3,583,613		3,649,088	476,849	355,291	121,558		
24	A New Zealand port £	2,198,711	1,991,900	4,190,611	1,600,000	391,900	1,008,989	997,817	11,172		

Port development and the national economy.

The economist teaches us to make a distinction between social and private net returns. The assumption is that if an enterprise yields an indisputable social net return then the enterprise is intrinsically good; whilst, if it yields a private net return, then it may be intrinsically good or it may not. In the latter case, the test is whether there is an adequate social net return in addition to the private net return. At the one end of this argument stands the last disciple of the extremist school of laissez-faire: at the other end, the believer in state ownership of all public utilities and much else. Commonsense is to be found, as always, somewhere between them—convinced, on the one hand, that the police force, the administration of justice and the country's defence (as examples) are jobs for national and local governments but equally sure that a woman wanting a new hat will be happiest and best satisfied if left to operate untrammelled as a potential customer in a free hat market.

As Bonavia remarks, however, " there is a frontier territory where private and public enterprises meet." The dock and harbour business is conducted on that frontier.

A country which must rely to any appreciable extent upon overseas trade, or to which the use of the coastwise seaway is important, must have a continuous care for the proper development of its seaports. The best expression of that care may often be to grant to the responsible port authorities, after due consideration and with sensible safeguards, such statutory and other powers as they may reasonably require, and then leave them alone to get on with their vital work. Even so, the national economy will touch port economy at many points. Some of them have been mentioned earlier—the Customs Service has its work to do at the ports and its legal requirements to make of port authorities: the Immigration Service, the Port Health Service, the Inspectorate of Factories, the Ministry of Labour, the Ministry of Transport, the Ministry of Fuel and Power, the Ministry of Local Government and Planning and H.M. Treasury have all got their regulatory functions to fulfil in association with the activities of port authorities.

In financial affairs, there are many port authorities, who, whilst having entirely autonomous constitutions, have benefited from time to time by Government assistance. In times when overseas trade has been bad, home industries depressed, unemployment growing and port revenues poor, the Government of the day has often found it advisable to make grants or low-interest-loans to port authorities to enable them to absorb some unemployed workers and, at the same time, improve or extend their port facilities against the return of better times. In the United Kingdom, the Distribution of Industry Act, 1945, makes special provision for monetary assistance from the Government to facilitate transport by water and other services upon which the development of the area depends, and there are similar enactments going back many years.

In the present year, 1952, and for some time past, the national economy has been deemed to require measures of the opposite sort—indeed, instead of receiving grants or loans from the Government, port authorities are being very largely discouraged from borrowing money, on their own responsibility, in the open market, for the purpose of improving their undertakings. This is part of the policy of general restriction of capital investment designed as one of the measures to curb the danger of inflation. It is reasonably urged by many responsible people that in public utilities there must be a point, even in circumstances such as those now obtaining in the United Kingdom, where it becomes less dangerous to spend than not to spend. It is a paramount aim of the present policy that production—especially production for export—must be

Port Economics—continued

increased. The transport system of the country, including the docks and harbours, is essential to increased productivity. If the existing ports, with their existing berthage and present equipment, are capable of dealing with all the ships and all the goods that the nation wants handling, and if the speed of working is all that it should be or might be, then port improvements may well be deferred. But, clearly, if that is not the case, then the national economy will benefit, both in the short run and in the long, if the port authorities are allowed to go ahead with all essential developments.

Increasing and decreasing returns.

It has been mentioned earlier that the generally accepted factors of production are land, labour and capital. No one of these three factors is perfectly substitutable for either of the other two, but, up to a point, the limitations of one of them may be compensated for by increased use of the others. It is this truth which gives rise to the economic laws of increasing and decreasing returns. It may be well to mention here that by "returns" the economist does not mean profits but gross product: and "land" is a wide term, inclusive of space, air, the sea, rivers and all natural resources.

A port authority exists to produce and sell safe, easily-approached and well-equipped berthage for ships—at tidal quays if it owns no enclosed docks, but also within the docks if such exist. The authority also has something to sell to the importer or exporter—namely quay facilities and, very often, shed or warehouse accommodation. If the authority goes in for stevedoring on its own account, it will also provide and sell loading and discharging services.

For port authorities, probably the most likely situation affected by the laws of increasing and decreasing returns occurs when the possibilities of the "land" factor have been temporarily or finally exhausted and the attempt is made to get more production by introducing more capital or more labour or both. Suppose a port authority to have jurisdiction over a given harbour and river and suppose that the available waterfront has been completely equipped with quayage so that no more "land" is available for quay construction: suppose, moreover, that the authority has spent a certain sum of money in equipping the quays with sheds, cranes and railway lines, and in providing locomotives and wagons, and is also regularly paying out a certain sum in wages to work-people to look after the quays and to operate the appliances. At any given moment, by calculating the interest on money spent on the facilities plus the total wages cost of their maintenance and operation, it will be possible to determine the money cost of the facilities and services provided. Theoretically, this cost can be related to each unit of the existing volume of production—a certain sum for every foot of berthage made available, a certain sum for every cubic yard of warehouse space and a certain sum for every ton of goods loaded or discharged. Suppose there is pressure on the existing facilities and it is desired to increase, to the utmost capacity, the total volume of facilities and services. There is no more land, so it is decided to increase the number of cranes and crane drivers, and engines and engine drivers, to build extra stories over the sheds, and to work all the berths for 24 hours a day instead of (say) the existing 16 hours. This means investing additional capital and spending more money on labour: and the volume of production will certainly be increased. There will be more loading and discharging capacity, more availability of quay accommodation and more space-tons of warehousing accommodation. It may well be that this new investment of capital and new expenditure on labour will, up to a point, result in additional production at the same unit cost as formerly obtained. This would be a phase of constant returns. It might even be, by reason of skilful planning and a shrewd appraisal of the possibilities, that, for a time, the overall cost of one unit of production might be lowered in comparison with the old regime. That would be a phase of increasing returns. But, as experienced port operators well know, there ultimately comes an end, in quayside economics, to the proverbial task of trying to get a quart into a pint pot. Overcrowded cranes cannot work to anything like capacity: transit sheds quickly filled cannot be emptied with corresponding speed: goods stacked to a great height, or carried by lifts to and from upper floors, take more time to handle and cost more in the process: in other words, the phase of diminishing returns has set in, and extra infusions of capital and labour do not produce anything like the old results. The end of this process is reached when the resultant increase in facilities and services made available is so slight as not to be worth the extra outlay.

A simple, everyday example of diminishing returns at the quayside is seen in the practice, frequently adopted in the interests of ship turnround, of "double-banking," that is, putting two cranes to work at one hold of a ship. The constant factor is "land"—that is, the size of the hatchway and working space available in the hold and around the quayside pitches. The stepped-up factors — by no means perfectly substitutable for "land" — are capital (two cranes instead of one) and labour (two gangs instead of one). Every quayside operator knows very well that by double-banking he will get faster delivery per hour from the hold than he would get from single crane working, but he also knows that he will not get **twice** as much. And if he has to resort to double-banking at night, by artificial light and paying overtime rates, he will get still less production for each man-hour. The explanations are natural and human enough, but there is no doubt that, in such circumstances, returns are of the diminishing order.

Some comparisons with other forms of transport.

Transport is moving persons and things. In our day, such movement takes place in ships across the seas, in smaller vessels along sea coasts, in yet smaller craft along rivers and canals, in railway trains (steam, electric, diesel, overland, overhead or underground), in road transport vehicles and in aircraft. Port undertakings are not so much transport arms as transport junctions or transhipment stations: but it may possibly interest the student and general reader to consider briefly some points of similarity and dissimilarity between port undertakings on the one hand, and, on the other, the arms of transport radiating to and from them—more particularly in the sphere of finance.

In the United Kingdom, the port undertaking and the water-borne vessel have one point of likeness and one of extreme unlikeness. They are similar in that they share the distinction of being the oldest co-workers in the business of transport; and they are dissimilar in that the financial structure of port undertakings generally reflects their public utility character: whilst the business of owning and operating ships remains as an outstanding example of private enterprise, commercial independence and merchant adventuring. Through the ages, their close association has been a marriage of opposites—a marriage, nevertheless, productive of some of the most vigorous and healthy elements in our national life. It may, however, not be out of place to remark here that there is a sharp need, in our day, for a special renewal of close and continuing co-operation between shipowners and port authorities; and this need springs from the basic difference between the economics of shipowning and those of port undertakings. A firm builds a ship in the entirely praiseworthy hope of making a profit out of her; they expect to run her for (say) 25 years and she will have all the sea to move about in; and the dominating principle governing her design and dimensions is the carriage of the greatest amount of cargo or the largest number of passengers that can be safely and profitably transported.. As against this, a port authority lays out its facilities to serve as many different sorts of ships and cargoes as possible; the capital investment is often very great indeed—so great that it takes much longer than 25 years to redeem it; the site is often restricted and there are apt to be many and various limitations upon design. These differences between the two economic bases are of radical importance. Clearly, the shipowner proposing to build a new ship is normally in more flexible circumstances than a port authority thinking of constructing new locks, docks and quays. It has lately been suggested, on behalf of shipowners, that port authorities should continuously build facilities to keep abreast of the requirements of new ships; but it will be evident to all that there is also much to be said for looking at the matter the other way. Certainly it would seem that a stage has been reached when fresh

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Diving Equipment and Appliances

III.—Underwater Television and Photography

(Specially Contributed)

THE possibility of employing underwater television in salvage operations is one which has, for some time, been carefully considered by experts, and it has been brought nearer to fulfilment by the use of this technique during the search for the wreck of H.M.S. Affray in the spring of 1951, when many difficulties and hazards were successfully overcome.

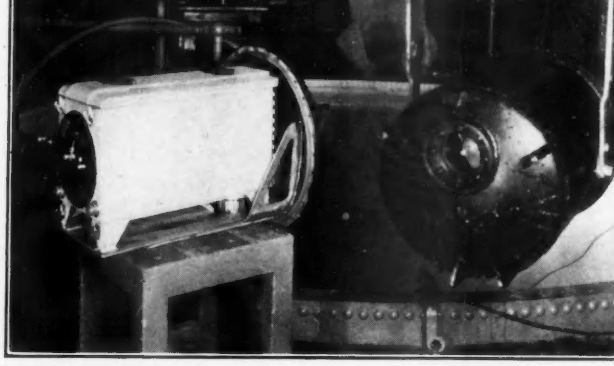
Scientists considered that the work might be greatly speeded up by the use of an underwater television camera, and the results actually achieved, exceeded the most optimistic hopes held at the start of the trials. Work was started at the beginning of May 1951 on the construction of an underwater casing to house the most suitable available television camera chain, and as speed was an essential factor in this work, no attempt was made to refine the design beyond the bare requirements of utility. No previous information was, at that time, available on the design or performance of underwater television, but considerable scientific research had been carried out on the performance of modern television chains and underwater cinephotography, the latter subject having been well covered in an article entitled "Underwater Photography" by J. B. Collins.*

The completed apparatus was installed in the deep diving ship H.M.S. Reclaim which sailed on May 27, 1951, equipped for the first time with this pioneer form of underwater eye. The television camera chain used was portable equipment manufactured by Marconi's Wireless Telegraph Company which is a type often used by the B.B.C. for outside broadcasts. On this occasion, it was worked on B.B.C. standards of 405 lines and 25 frames per second, interlaced. It incorporated an Image Orthicon pick-up tube made by the English Electric Valve Company. This is the most sensitive type of camera pick-up made, but it is also very complex, and later we shall consider it in detail.

The waveform generators and camera control equipment were installed, mainly for security reasons, in the captain's cabin in H.M.S. Reclaim and connected to the camera which was worked from a derrick on the well-deck, by 500-ft. of multicore cable specially provided by the British Insulated Cable Company with an extra heavy protective sheath of polyvinyl chloride. Apart from a small screen for the benefit of the camera control operator, and also used for photography, the main viewing screen was an English Electric domestic television receiver adapted to accept signals straight from the camera chain. No modifications were made to the electronic circuit but some additional instrumentation was added, using spare cores in the camera cable which normally carry communication to the camera operator. These included remote operation of a fan and heater, with indication of the temperature in the camera, since maintenance of correct temperature is essential for correct operation of the pick-up tube. A remote reading level meter and a very ingenious leak detector were also fitted.

The underwater casing was a welded steel cylinder 24-in. long and 17-in. in diameter, similar in appearance to a domestic dustbin. The bottom end was made detachable by a flanged and bolted joint with unmachined surfaces, and to this was attached the camera, window mounting and cable gland. No space was available for shock absorbent mountings and advantage was therefore taken of the inherent springiness of the camera bracket. The window was of ordinary plate glass with a clear aperture 3-in. in diameter and having a thickness of $\frac{5}{8}$-in. At the time of manufacture, maximum expected operating depth was about 200-ft.; the casing has, in fact, stood up to a depth of 285-ft. and some considerable bumping. This must be attributed to a certain amount of luck and to some experience in design, rather than to any carefully calculated factor of safety.

One of the most ingenious and simple gadgets incorporated in the casing was a piece of blotting paper placed in a suitable position within the casing, the electrical resistance of which could be continuously monitored from the surface. Any leakage of seawater reaching the blotting paper resulted in low electrical resistance. This was simple enough to be completely reliable and was nicknamed the "dampometer"; it has saved the camera from serious damage on one occasion and has always been a great comfort to the remote operator of the camera. Apart from "teething



The new Marconi underwater television camera undergoing tests in a tank at the laboratories of Siebe, Gorman and Co. Ltd. *Left,* the camera; *right,* the pressure casing showing the lens window.

trouble" due to a cracked brazed joint in the casing, no leaks have occurred. On one occasion, the outer sheathing of the camera cable was punctured at a distance of about 60-ft. from the camera, and the water forced its way down the cable into the camera itself. It is a tribute to the cable that, until shown on the "dampometer," there were no electrical indications that it had been flooded.

On two occasions, when operating below 250-ft. the camera

*Journal of the Royal Naval Scientific Service, November 1949.

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and full consultation between port authorities and shipowners is urgently necessary.

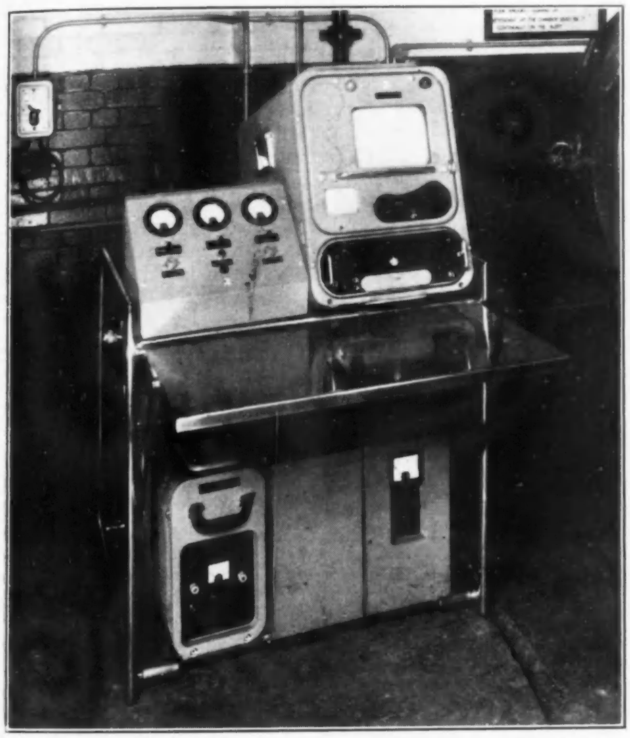
We can think of the main transport system of the world as being made up of ships, ports, rivers, canals, railways, road transport and the air route. When the various agencies are thus grouped in a single sentence one fact immediately stands out—some get their track for nothing, others have to make and maintain track as well as vehicles. For railways, track costs make heavy demands on capital and on revenue; the airplane and flying boat get theirs free; the ocean liner has free track at sea but usually pays for the use of harbours, rivers or docks; the canal carrier pays a toll; the road transporter uses an artificial track made at the public expense for general use and he contributes something towards its upkeep; whilst port authorities control harbours and rivers but most often have to invest capital and expend revenue in order to make and keep them suitable for use.

There is an interesting similarity between air transport and a port authority owning and operating enclosed docks, in that in both cases large sums of money are always being spent in order to do something which is against natural laws. A large part of the expenditure on aircraft is required simply to defeat the pull of gravity; whilst the heavy cost of building and maintaining enclosed docks is undertaken to avoid tidal effects. A wise and experienced port manager of the last generation once remarked that it is fairly easy to make money in the river but even easier to lose it in the docks.

Diving Equipment and Appliances—continued

came up with a cracked window; in both cases it also had a severe bumping, but no water had leaked through the cracks, complete collapse of the window having been prevented by the very wide gripping area of the window mounting. The mounting was therefore replaced by a more rigid structure and the thickness of the window was increased to ¾-in., since when no further damage has occurred. Lighting was provided by a 1½ kW tungsten diver's lamp lashed to the tubular frame, the purpose of the latter being mainly to support the lighting, but it also acted as a protector for the camera and as a structure on which it could safely rest when swung inboard.

A shield prevented direct light from reaching the lens and minimised the illumination of the water path between the lens and the object. For optimum visibility the source of light should have been further from the camera, but for ease of handling the frame, the one actually used was the largest practicable, and when this was rendered unusable by repeated damage in collision with wrecks, it was replaced by a smaller structure. Sheet metal fins



The control desk of the Marconi underwater television camera showing the remote control equipment and master monitor.

were originally used to keep the camera steady in a tideway, but these were later discarded as unnecessary.

Development of the underwater television apparatus since then was carried out mainly at Tolworth, Surrey, by close collaboration between Siebe, Gorman and Co., Ltd., and Marconi's Wireless Telegraph Co., Ltd. This collaboration is essentially practical, since problems of the underwater world are quite outside the experience of the radio industry, and the solution of many of the difficulties encountered by this new technique would never have been possible without the aid of expert knowledge of submarine conditions.

Underwater television starts with a marked advantage over other means of submarine exploration, as a camera within a pressure-casing is capable of seeing all that a man in a diving bell can see. Indeed, in this particular case, it can see far more, because the Image Orthicon is the most sensitive type of instrument of its kind yet evolved, and is, in fact, more sensitive than the human eye. It has already proved itself capable of reporting to the television screen far more detailed and reliable material for study, scrutiny and recording than can be obtained from reports and samples of divers, and it is able to work under water for a far longer time than a diver can. Moreover, it can go deeper than a diver, and it can be raised and lowered much more quickly; it can also be used in places too difficult and too dangerous for a diver to reach. The pictures that it sends to the screen can be examined by experts in comfort, free from distraction and danger, and therefore able to form a careful and balanced judgment of underwater conditions. In addition, pictures can be photographed off the screen for detailed analysis and permanent record.

Identification of the submarine H.M.S. Affray gave ample proof of the surprising versatility of the Marconi camera and the sensitivity of the Image Orthicon tube. At a depth of 285-ft. below the sea, by the light of a single 1½ kW diver's lamp, this remarkable instrument had picked out from a distance of about 8-ft. the six-inch brass letter Affray on the grey conning tower of the submarine, and it gave a clear image of them on the screen in the captain's cabin in H.M.S. Reclaim. In later tank experiments, it was found to be capable of providing reasonable pictures from a depth of 80-ft. even by natural daylight.

Modifications necessary to the camera itself mainly concerned problems of remote control. The present equipment comprises a standard Marconi Image Orthicon camera adapted for remote control of focus and iris, mounted in a pressure casing and linked to the controls in the ship through a specially designed gland by a multi-core camera cable specially sheathed for underwater work. Mounted in the ship at the other end of the cable are the controls, the waveform generators and the monitors with viewing screens. Instead of the four turret-mounted interchangeable Dalmeyer lenses carried by the standard camera, a single special wide-angle lens is fitted. A small electric motor attached to the camera operates the focus and iris of the lens. Since the Image Orthicon tube depends on the maintenance of an even temperature for its most efficient working, provision had to be made for a fan and heating apparatus. All these controls are effected through spare channels in the standard multi-core cable.

The pressure cylinder is fabricated by welding of mild steel 5/16-in. thick, 29-in. long with an internal diameter of 19½-in. and a maximum external diameter of 22-in. over the single flange. The camera itself is mounted on a plate welded to the back plate of the casing to which is also attached to the camera cable gland. The front plate of the casing carries the window, a spherical viewing port ½-in. thick and slightly less than 5-in. in diameter, specially made for the purpose. Problems arising from the control of this casing, and of the camera inside it, have called for the provision of an indicator showing the inclination of the unit and the device known as the "dampometer" for indicating leakage, to which we have already referred. Artificial illumination of underwater subjects can be provided by lamps mounted on a gantry surrounding the pressure-casing and controlled from the ship.

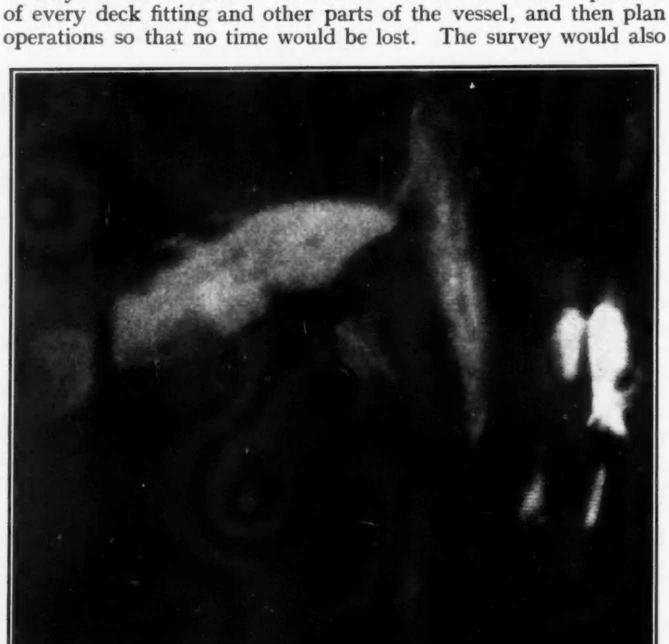
The dock and harbour engineer will obviously be interested in the problems of controlling this apparatus in tidal waters at different levels and subjected to the action of conflicting currents, so that for efficient use the camera must be capable of easy and rapid traverse and elevation. Also it has to be aimed at, and kept on, the target under view. Northern waters are murky even at the best of times, but apart from this, detailed observation means close observation, which in turn means that the camera has to be handled with precision. Handling gear must therefore be extremely flexible, and the present practice is to suspend the casing on a ⅛-in. diameter non-spin wire swung outboard on the ship's own derrick. In practice it is found that flexibility and control are not easily compatible under submarine conditions. One of the most profitable uses of underwater television for dock and harbour work is likely to be examination of objects on or near the sea-bed, but a camera suspended from a vessel rising and falling on the surface will certainly need some form of compensating gear to maintain it in position anywhere near the sea-bed itself, so as to prevent it from repeatedly being "bumped on the floor."

It should be borne in mind that underwater television is still in the very early pioneering stage, and it is therefore necessary to keep the role of this new and valuable technique in proper

Diving Equipment and Appliances—continued

perspective from a practical engineering viewpoint. It is suggested, however, that it will be possible to employ a pair of underwater television cameras in such a manner that a pair of photographs can be taken of some underwater object, such as a wreck, so that the overlap is about 60 per cent., and a stereoscopic pair of photographs can thus be obtained by suitable adjustment of the spacing between the cameras and the television screen in the cabin on board the ship. Such spacings will, of course, correspond to the spacings of the two television cameras under water and their distance from the wreck. A complete survey of the wreck can thus be made by these means, as it should be possible to obtain stereoscopic pairs of photographs from various positions and then construct a scale model of the wreck in the same manner as similar sets of photographs are employed in air surveys.

Such a precise scale model would be of value to salvage experts, as they would be able to see on the model the relative position of every deck fitting and other parts of the vessel, and then plan operations so that no time would be lost. The survey would also



A photograph taken from the television screen showing underwater life at low depth where it would be impossible for the human eye to identify anything.

disclose the amount of silting against the hull, the precise angle at which it was lying, and, in fact, would give a three-dimensional view of conditions, which would be of great practical value. It is interesting to note, in passing, that when H.M.S. Breconshire was salvaged off Malta by the Admiralty Salvage Organisation, use was made of a 12-ft. scale model for studying the stability conditions of the hull.

During the diving period from May 27th to June 1st, 1951, experience was gained in the operation and handling of the underwater television gear from H.M.S. Reclaim. In conjunction with observations by divers, increasing confidence was felt in the ability of the camera, not only to identify the nature of a wreck, but also to help the diver so that his shot-rope could be placed in a suitable position. Problems of handling the camera proved, in the event, not to be so difficult as had been anticipated. To move the camera to a desired position, the whole ship was shifted by altering the mooring cables and/or wire. Range of visibility proved to be at least 15-ft. and often more, when the diver's visibility was only 5-ft. This may have been partly due to the superior lighting provided for the camera. The somewhat restricted field of view, and lack of facilities for altering the direction of view when under water, limited the area of wreck which could be scanned at one time, and rendered the building up of a complete mental picture rather difficult. The camera could be used, however, for at least two hours every slack water, as opposed to the few minutes possible for the diver, so that the amount of extra information gathered was very considerable.

During the next diving period from June 6th to 16th, results at first were similar to those obtained during the previous trials. Confidence in the camera had increased to such an extent that one contact was identified and cleared in two days by the use of the camera without any diving being necessary. On the evening of June 13th orders were given to H.M.S. Reclaim to investigate a contact further south than the previous search area, and in a reported depth of 47 fathoms. By midday slack water on the 14th the contact had been located and H.M.S. Reclaim was moored over it. It was decided that, owing to the depth, the Reclaim observation chamber should be employed. It reported a wreck, not very clearly seen, which could be a submarine. The camera was then lowered cautiously until the viewers in the captain's cabin of H.M.S. Reclaim saw the name Affray on the screen and there was then no further doubt about the matter; some hours later divers were able to identify the submarine by normal methods.

Photographs published in the press at the time were merely snapshots taken with a hand-held camera of the television screen, so that there was inevitably loss of quality. The information that the Affray had been found was released on July 14th solely on the evidence provided by underwater television.

Further work carried out on the site of the wreck of the Affray is of considerable interest to those who are concerned with salvage and similar problems. Much of this survey was carried out with the television camera, and some two hundred detail photographs were obtained of various parts of the hull and fittings which have proved to be of great practical value in helping the deliberations of the Board of Inquiry into the disaster. Recovery of the damaged snort mast, the head of which was lying on the sea-bed at a depth of about 280-ft., was a hazardous diving operation in which the camera played a very important part. It was used to place the diver's shot, weighing half-a-ton, within a few inches of the snort's head, and to ensure that the shot-rope was clear of the periscope standards to enable the diver to descend in safety. In all, the shot was positioned five times before the lifting wire was finally secured to the head. Time saved by using the camera for this purpose was, in the opinion of the diving experts, about a month. The value of the diver being able to see an object before he descends need hardly be stressed, and this new facility is likely to have a profound effect on the conduct of salvage operations in the future.

The camera has also been successfully employed in the operation of a salvage grab and of an electro-magnetic "grab." The direct pictures obtained of these made manœuvring far simpler than is normally the case by telephonic communication with an observation chamber. The ability to employ a television camera in conjunction with various remotely controlled underwater tools such as grabs and grapnels, is likely to facilitate work on wrecks and salvage operations generally. As far as deep diving is concerned, it has now established itself as an essential adjunct to such operations. Steps are now being taken to provide an improved version of the apparatus used on the Affray, which will have a casing of improved design, and will be provided with facilities for focussing the camera optically, for changing lenses and for altering the aperture under water. Field of view will be much greater than before, and the possibility of using spherical windows will be investigated, thereby increasing the field of view still further.

New Medical Centres at Hull.

Two newly built Medical Centres at the King George V Dock and Alexandra Dock were opened at Hull early last month by the National Dock Labour Board. The new centres are modern and unique in design and are the first to be provided in the Hull and Goole area. A smaller centre at Victoria Dock is nearing completion, and a site has been cleared and foundations laid for a similar centre at the Royal Dock. The number of Medical Centres now in operation is 33, covering 17 ports, and the fact that more than 240,000 treatments were given during 1951 is a measure of the value which dockers attach to the new service.

High Manganese Steel

High or austenitic manganese steel was first discovered by Robert Hadfield in 1882 in the endeavour to discover a steel suitable for the wheels of tramway cars. It is an exceptionally tough alloy of non-magnetic type, its characteristic properties being high strength, high ductility, and excellent resistance to wear. It can be obtained in either rolled bars or castings, and has a wide industrial application, being probably the best possible material for those parts in which maximum resistance is required to abrasion severe impact.

Before its invention, a metal possessing great ductility and hardness at one and the same time was not available to industry. In unalloyed steels, to obtain greater hardness it is essential to sacrifice a measure of toughness, or on the other hand, if greater toughness is required, a degree of hardness must be given up. This is not the case with high manganese steel.

It contains approximately 12 per cent. of manganese, though the permissible range is 11 to 14 per cent., with 1.2 per cent. carbon. On average, the composition usually lies between 12 and 13 per cent. because the lower limit of the range gives a steel with lower tensile strength, while the upper limit does not give advantages sufficient to compensate for the higher cost. The carbon content has a degree of influence on the yield strength, which is lower as the carbon content decreases. Carbon above 1.2 per cent. is liable to make heat treatment more difficult.

Although, as we shall see, the tensile strength of manganese steel is a useful indication of its toughness, the most remarkable property of the material is its resistance to abrasive wear. It is not hard in the generally accepted sense of the term. The Brinell number, when the steel has been toughened by quenching it in water, being from 187 to 207, even when it has been forged and heat-treated. Ordinary steel, however hard, can be readily machined, if heated and then allowed to cool slowly, but neither this nor any other procedure can render manganese steel readily machinable. This fact has, to some extent, limited its use, because of the difficulty of cutting it to shape. Commercially, it can only be cut or drilled by either super-high-speed steel tools containing a high cobalt content or by tungsten carbide tipped tools. For drilling, it is essential to employ short, stubby twist drills of special design and using a special technique, the principal features of which are that the material must be drilled *dry* and with no interruption of the cutting operation, which must be continuous.

The ductility of manganese steel, a particularly valuable property, can be considerably influenced by the rate of cooling after heat-treatment. Sudden cooling makes the material extremely ductile, whereas slow cooling renders it brittle.

What, then, renders the machining of this steel so difficult? The answer is briefly, that when the steel is subjected to deformation by cutting, crushing, rolling etc., its molecular surface structure is altered, and its hardness may be more than doubled. This is not because of any change in composition, nor a result of raised temperature, but is solely the effect of structural deformation. It will be appreciated that a lathe tool will cause deformation of the surface structure, so producing the superficial hardness that makes it difficult to turn or drill the steel. Figs. 1 and 2 clearly show the alteration brought about in the structure of the steel by cold working. This effect is known as work-hardening.

As an illustration of the toughness of the material, tests taken on 4-in. diameter dredger pins are given below. The test pieces were forged from pins chosen at random, and were water-toughened from the same temperature as the pins they represent. Four different casts of steel are represented by these tests, and the figures afford striking proof of the exceptional toughness of the material. The bend tests consisted of bending a piece ¾-in. square to an angle of 120 degrees, and afterwards doubling it up flat without its revealing any signs of fracture.

Test No.	Testpiece Size	Max. Stress per sq. in.	Elongn. per cent.	Reduction of Area per cent.
1	.564 dia. x 4-in.	76.0	75.0	42.0
2	ditto	74.0	72.5	44.1
3	ditto	74.9	76.0	54.2
4	ditto	74.1	75.0	55.6

The composition of the steel also includes from 1 to 2 per cent. silicon. Sulphur and phosphorus are present as impurities, but are kept as low as possible.

A property of great importance from the point of view of the user is the relatively low elastic ratio, the significance of which is that there is a great disparity between the point at which, under load, the steel first takes a permanent set, and that at which it eventually breaks.

Manganese steel is beyond question the best material for all purposes in which heavy wear has to be met, by reason of its toughness, exceptional surface-hardness when abraded, and low elastic ratio. A distinction must, however, be drawn between heavy wear and heavy shock or percussion. When it is necessary for a part to withstand severe shock, it is not always advisable to make it of high manganese steel, which tends to flow or spread laterally in these circumstances, by reason of the low elastic ratio. It is always advisable to consult the steel manufacturer wherever there is doubt concerning the steel's suitability for a particular part or purpose.

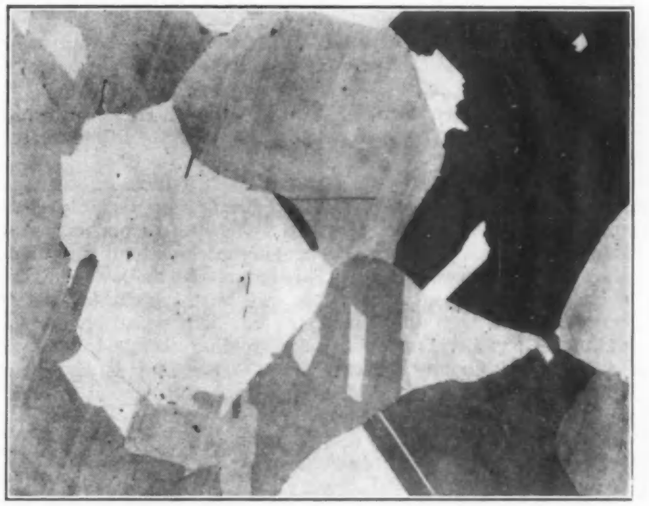


Fig. 1. Austenitic manganese steel in the water-toughened condition.

What makes manganese steel ideal for such parts as dredger buckets, lips, pins, bushes, and links, is its ability to work-harden. The maximum hardness attainable in practice is about 550 Brinell. Hardening is produced by deformation, so that any attempt deliberately to harden the material by working it must make suitable allowance for lateral flow. Work hardening is generally induced by impact, as from the blows of a hammer. Light blows, even if of high velocity, will set up shallow deformation with surface hardening, though the surface hardness may be considerable. Severe impact sets up deeper hardening, usually with lower maximum values.

When high manganese steel is being considered for abrasive service in dredging plant, excavating machinery, crushing and grinding machinery, trackwork, etc., the primary factor in selection should be toughness rather than ability to withstand abrasive wear. If impact and shock are absent, as in pipe carrying sand-laden water, a martensitic cast iron is a much superior material. If light or moderate impact is likely to be encountered, a hardened steel may be suitable, but skilled judgment is necessary before giving up toughness in favour of resistance to abrasion. On the other hand, if heavy impact is expected or a large safety-factor required, high manganese steel is the best choice. The initial cost of the part must also be taken into account. If the cost of replacement is heavy and length of service life of maximum importance, while the abrasive wear is known to be severe, then high manganese steel may be essential, even if not so tough as alternative materials.

It has been suggested that unless it has already been work-hardened, high manganese steel is not adequately wear-resistant. This is untrue. The longer service life of the steel as compared to other metals in certain conditions of service has led users to assume erroneously that the vastly longer life is the result solely of the work-hardened of the surface of the steel. There are, it

High Manganese Steel—continued

must be pointed out, instances in which the resistance of high manganese steel to abrasion is not greatly affected by work-hardening, and others in which it will outwear even the harder pearlitic white cast irons in the absence of work-hardening. Manganese steel is not sufficiently resistant to wear from an air-borne stream of abrasive particles, so that there is no advantage in using it for such service.

The properties of high manganese steel at elevated temperatures are less good than those of the stainless steels or heat-resisting steels, and in addition, this steel is liable to become brittle when heated, so that it should be rejected for any work involving frictional heat liable to rise above 260 deg. C. Neither is high manganese steel resistant to corrosion. It is readily attacked by rust, and conditions involving corrosion and abrasion in combination are liable to cause rapid and uneconomical deterioration.

Like most steels with an austenitic structure, manganese steel retains its toughness at low temperature, and has its best properties at temperatures between 100 and 200 deg. C. It expands similarly to other materials of austenitic type. The anticipated change in length during heating is about $1\frac{1}{2}$ times that of the ferritic steels. The coefficient of linear expansion at room temperature is 0.000018-in. per in. per deg. C. Being non-magnetic, the steel in either cast or wrought iron form is probably the strongest and most economical steel for non-magnetic parts such as lifting magnet covers.

Additions of nickel to the standard composition of austenitic manganese steel do not alter its yield strength appreciably, but a higher tensile elongation is obtained. A lower carbon content is much more influential in producing toughness without quenching, and as the addition of nickel appears to prevent the lower intrinsic toughness of 12 per cent. manganese steels with low carbon content, a range of steels with 0.6 to 0.9 per cent. carbon and about 3 per cent. nickel has been introduced for welding rods, wrought products, and occasionally for cast parts. This alloy is also better than the standard alloy in resistance to embrittlement resulting from reheating up to 420 deg. C.

A chromium cast manganese steel is another innovation, said to have higher yield strength and resistance to flow, slightly better resistance to corrosion, and smaller liability to embrittlement by reheating. There are also claims that it has a higher degree of wear resistance than the standard composition, but this has yet to be established.

Dredger pins and bushes made from this material, i.e. the standard composition, are usually tested in ring gauges for the outside diameter. The bushes are tried in pin gauges for the bore, to ensure that the requisite accuracy is obtained. Diversity of opinion exists as to the relative merits of forged or cast split bushes. Advocates of the cast bush claim that it can be produced more

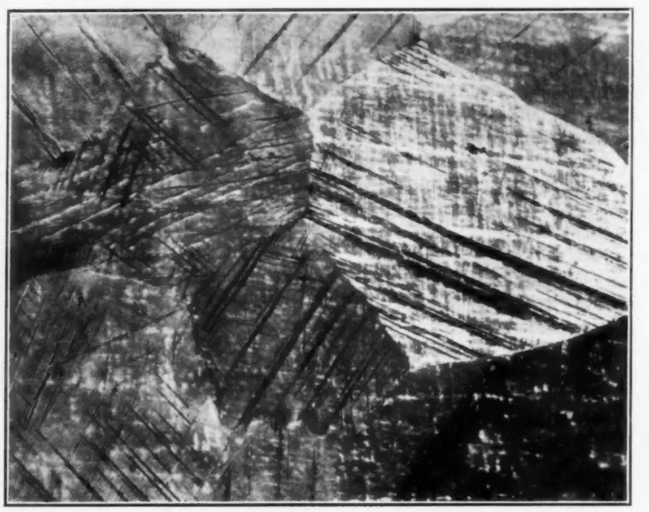


Fig. 2. Austenitic manganese steel in the water-toughened condition after cold working.

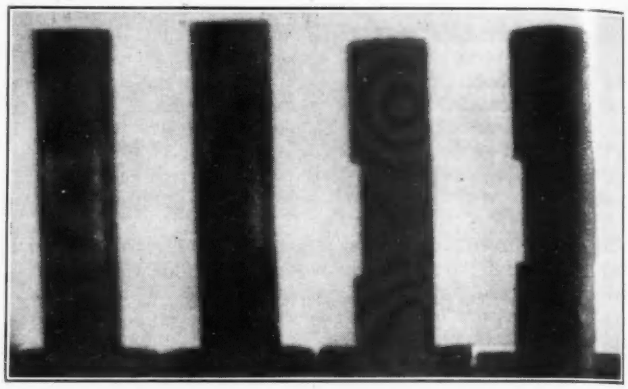


Fig. 3. Actual photograph showing superior wear resistance of high manganese steel dredger pins.

quickly and sold at a rather lower price than the forged type, at all events in the larger sizes. On the other hand, many users regard the forged type as superior because the additional work put into the steel by the forging operation improves its structure.

As an example of the superior resistance of high manganese steel Fig. 3 may be of interest. It shows the state of two sets of high manganese steel dredger pins after about six months of dredging. An equal number of pins of both makes were put in at the beginning of the season, so that all the pins were working under the same conditions. This dredger was used in dredging harbours with extremely hard and rocky bottoms. The pins on the left were made of austenitic maganese steel. The others were made of a less effective material. In addition to pins and bushes, other parts of dredgers are made of this wear-resistant steel. Dredger parts are, of course, subjected to hard wear and severe strains. The lip of the bucket which scoops out the material naturally receives most of this, and in consequence it was at one time usual to secure a detachable and renewable high manganese steel lip to the permanent bucket. This did away with the necessity of renewing the entire bucket when the lip wore out. This trouble has now been overcome in other ways. Dredger tumblers, bucket backs, chain links, etc. are made from this steel. Some tumblers are made solid, with no splits whatsoever in the boss, and these have proved most successful; not in one instance has the shaft worked loose, as was often the case with tumblers having split bosses.

The steel can be supplied in the form of cast parts, rolled bars, sheets, forgings and rails. In the forged and heat-treated condition it has a tensile strength of 5 tons per sq. in. and over, and an elongation of about 40 per cent. in 4-in. The steel shrinks much more than ordinary cast steel when cooling, and therefore an allowance of 5/16-in. per foot must be made for patterns for castings.

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